Adaptive Call Admission Control for Prioritized Adaptive services in Wireless/Mobile multimedia Cellular Networks

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Summary
New generation cellular wireless networks are designed to support adaptive multimedia services by controlling individual ongoing flows to increase or decrease their bandwidth in response to changes in traffic load. There is growing interest in quality of service (QoS) provisioning under this adaptive multimedia framework, in which a bandwidth adaptation algorithm needs to be used in conjunction with the call admission control algorithm. In this paper, we introduce an adaptive CAC algorithm to complement resource reservation mechanism and the ability of robust applications to sustain performance fluctuations. The proposed algorithm correlates the current status of resource consumption and scalable degradation via the derivations of several correlation index indicators. The result acquired from the extensive discrete event simulation developed has shown the ability for the proposed algorithm to enable a substantial enhancement to the static call admission control algorithms. The versatility provided by the proposed algorithm enable the elevation of call droppings to a substantial reduction level.

Key words:
adaptive multimedia frameworks, quality of services, wireless/mobile cellular networks, call admission control, discrete-event simulation.

1. Introduction

Wireless/Mobile communications systems are becoming increasingly popular as they provide users the convenience of access to information and services anytime, anywhere and in any format. The upcoming wireless cellular infrastructures such as third generation (3G) and fourth generation (4G) are deemed to support new high-speed services with different Quality-of-Service (QoS) and their respective traffic profiles. The expected services will include multimedia services that need real-time QoS guarantees. Different wireless multimedia services have diverse bandwidth and QoS requirements, which need to be guaranteed by the wireless cellular networks. To achieve this goal, QoS provisioning in wireless multimedia networks is critical.

In wireless/Mobile cellular networks, a mobile user's QoS requirements can be objectively expressed in terms of probabilistic connection-level QoS parameters related to connection establishment and management, such as New-Call Blocking Probability (NCBP) and Handoff Call Dropping Probability (HCDP) [1]. The NCBP is the probability that a new call will be rejected; a measure of service connectivity. New call blocking occurs when the entire bandwidth of the wireless system medium is busy upon a new call request. The HCDP is the probability that a handoff call will be rejected; it measures service continuity during handoffs. The procedure of moving from one cell to another, while the call is in progress, is called handoff. To fulfill handoff, the mobile requires that the base station in the cell that it moves into allocate the required bandwidth. If no bandwidth is available in the new cell, the handoff connection is dropped. This kind of dropping refers to blocking of ongoing connections due to the mobility of the users. Since call dropping of established connections is usually more annoying than rejection of a new connection request, it is widely believed that a wireless cellular network must give handoff connection requests a higher priority than is given to new connection requests.

Provisioning connection-level QoS in wireless cellular networks is complex due to the limited radio-link bandwidth, the highly fluctuating wireless environment and the user's mobility. The problem has become even more challenging as recent wireless cellular networks have been implemented based on small-sized cells (i.e., microcells or picocells [2]). These cells are intended to allow higher transmission capacity and thus to achieve better performance. However, they also increase the handoff rate and result in rapid changes in the network traffic conditions, making the assurance of QoS guarantees more difficult [3]. Therefore, the most important connection-level QoS issue that should be addressed is how to reduce/control handoff drops due to lack of available resources in the new cell, since mobile users should be able to continue their ongoing connections. Designing an efficient mechanism for management and sharing of bandwidth among different types of traffic with different classes is another important issue that plays a major role in enhancing system performance.

Recently, in order to overcome the limitations of scarce, highly fluctuating link bandwidth in wireless multimedia networks, adaptive multimedia networking has been proposed (e.g., [4-5]). An adaptive multimedia paradigm can play an important role in mitigating the highly varying resource availability in wireless multimedia networks.

Manuscript revised March 25, 2006.

After call setup and during a call's lifetime, the assigned service call bandwidth of multimedia class is fixed in most existing mobile cellular networks. However in the adaptive framework, the bandwidth of an ongoing call is variable and thus can be dynamically adjusted to adapt to various communication environments, especially in situations of overload traffic. With the help of this adaptive framework and the aid of an efficient bandwidth allocation mechanism, the dropping probability of handoff calls is reduced to a negligible level in moderate traffic load when the minimum bandwidth of a call is sufficiently small in an adaptive framework [5-6]. However, even though the HCDP drops to almost zero within the adaptive multimedia framework, QoS provisioning for multimedia in wireless cellular networks remains a challenge in overload situations.

A call admission control (CAC) algorithm is another key factor that enables efficient system resource utilization while ensuring that connection-level QoS requirements are satisfied. CAC is always performed when a mobile initiates communication in a new cell, either through a new call or a handoff.

In this paper, we introduce an adaptive CAC algorithm to complement resource reservation mechanism and the ability of robust applications to sustain performance fluctuations. The proposed algorithm correlates the current status of resource consumption and scalable degradation via the derivations of several correlation index indicators. The paper is presented in the following order; Section 2 reviews the progressive development of the incorporation of algorithms to cushion the effect of multimedia variance. This is followed by a detail discussion on the proposed algorithm and the newly derived correlation indexes. Section 4 presents the details of the Discrete-Event Simulator developed for the purpose of wireless cellular performance analysis. The results and discussions section is presented in Section 5. The paper is concluded in Section 6.

2. Call Admission Controls Algorithms

During the past decade, intensive research has been done and various handoff priority-based CAC schemes have been investigated. In [7-10], the well-known guard channel scheme and its variations were proposed to give higher priority to handoff connections over new connections by reserving a number of channels called guard channels for handoff call connections. All these schemes are static in the sense that the number of guard channels is determined mainly based on a priori knowledge of the traffic patterns, thereby being unable to cope with network dynamics. Moreover, only one traffic class, i.e., voice traffic, is considered. There have been a few guard channel-based schemes supporting voice and data traffic in an integrated mobile network [11-14].

Recently, several CAC algorithms and bandwidth adaptation algorithms (BAAs) have been proposed in wireless networks [15-20]. In [15-17], it is assumed that all calls belong to a single class of adaptive multimedia traffic and receive varying bandwidth assignments from a discrete set of integer bandwidth values. An analytical model for wireless networks with adaptive bandwidth allocation and a traffic restricting CAC is derived in [15]. In [16] and [17], new QoS parameters for adaptive multimedia in wireless networks are introduced. Cell overload probability parameter is proposed in [17]. Multiple classes of adaptive multimedia services in cellular wireless networks have been introduced in the literature [18-20] without considering the prioritization between new call arrivals and handoff calls for each class of traffic. However, in our framework we provide a bandwidth allocation policy that takes into account the separation between incoming traffic for each class and prioritizes handoff calls over new calls. A prioritization in the process of bandwidth adaptation among multiple classes of multimedia services is presented in [20] where the bandwidth of calls with lower priority is preferably adapted. However, in this approach the authors assume no handoff dropping which make their work impractical. This is not the case in our work since a handoff call can be dropped if it doesn't satisfy the adaptation condition.

Reviewing the algorithms above, a distinct parameter to capture ratio of performance to the multi-level resource allocation is not present. Thus, in this research we present a novel adaptive multimedia framework for the next generation of wireless/mobile cellular networks at the connection level, where the bandwidth allocated to the ongoing calls can be dynamically adjusted. This framework supports multiple classes of fixed and adaptive multimedia services with diverse QoS requirements.

The design of the Adaptive Call Admission Control Algorithm (Ad-CAC) is tailored to achieve the following implementation goals:

i. establishing a priority mechanism for different types of traffic;
ii. developing a framework to handle different types of traffic instead of only one as proposed in most of the current research;
iii. establishing a priority mechanism for handoff calls over new calls;
iv. maximizing the bandwidth utilization;
v. reducing the information exchange among base stations;

The following section presents the details of the algorithm to achieve the stipulated design goals.

3. The Proposed Algorithm

The proposed Ad-CAC encompasses the following the components: bandwidth allocation/reallocation policy, CAC algorithm, and bandwidth adaptation algorithm.

3.1 Bandwidth Reallocation Policy

Under conditions of heavy traffic load, i.e. the sum of the requested bandwidth exceeds the unused bandwidth capacity so that not all the requests can be completely served, the role of bandwidth adaptation technique are essential. These algorithms are needed to reduce the requested or already connected call bandwidth allocation. In designing the algorithm, we assume that a service with degraded QoS is better than an outright rejection of service requests. The quality grade is determined by the amount of Acceptable Bandwidth level (ABL).

The Bandwidth Reallocation (i.e. degradation or upgrading of resource allocation) module is deployed to reallocate the bandwidth capacity. The reallocation forms the crust of the scheme/algorithm. The strategy implemented is by cohesively coupling lower and priority calls in a trade-off manner. In the event of a new call or handoff from a higher priority traffic encountering insufficient bandwidth level, sustaining the call is compulsory in the presence of hybrid traffic. Bandwidth of lower priority connections (i.e. non-real-time and real-time VBR traffic) are decreased to the level of streams of the lowest priority or the highest ABL. In the event of a vise versa conditions, bandwidth of lower priority traffic are able to be increased to a maximum level of the highest priority level. The process of reallocating may be involve either an upgrade or degrade of the bandwidth allocation based on the ABL.

The ABL is obtained by subtracting the maximum required bandwidth with the minimum required bandwidth. The difference is called the degradable range/spectrum. The degradable spectrum is further divided into N (i.e. where N = 1, 2, …n) levels, called micro-ABLs as shown in Fig.1. The concept of bandwidth allocation as a discrete component is applied into the structuring and derivation of the micro-ABLs. Subsequent to this theory, the bandwidth allocation for the micro-ABLs form the discrete set B= $\{BW_{Min}, BW_{Min+1}, BW_{Min+2}, \ldots, BW_{Avg}, \ldots, BW_{Max}\}$ where $BW_{Min+i} < BW_{Min+(i+1)}$, BW_{Min} is the minimum bound , BW_{Avg} is the average bound and BW_{Max} is the maximum bound for bandwidth allocation.

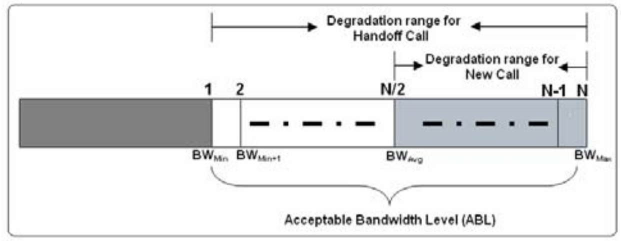

Fig.1: ABL and Micro-ABLs range/spectrum

The computation and deployment of bandwidth reallocation consumes an amount of time capable of jeopardizing the probability of a mobile to continue is connection. Thus, to avoid this time delay, the process of bandwidth reallocation is carried out in a distributed manner. Each Base Station (BS) does the computation process independent from other BSs. An important pre-requisite is to ensure that the computation process of bandwidth reallocation algorithm should be completed before the system does the real bandwidth reallocation of the ongoing connections in the network. The essence of the proposed Ad-CAC is the cohesive working nature between the resource allocation/reallocation and the CAC. The CAC is elaborated in the following sub-section.

3.2 Ad-CAC and ABA Algorithms

The proposed Adaptation Bandwidth Algorithms (ABA) is utilized to adaptive determine the bandwidth for call admission. The algorithm will be triggered whenever there is a call arrival acceptance event or a service departure event. In this work, our objectives are to minimize NCBP, HCDP and to efficiently utilize the system resources.

Fig.2 elaborated the proposed CAC algorithm. Ideally, every call in a cell should be allocated the maximum bandwidth (BW_{Max}) whenever possible. However, if the cell is over-loaded, some of the calls in the cell might receive a bandwidth lower than the requested bandwidth. When a new call or a handoff call arrives, some of the calls already in the cell are made to lower their bandwidth (the minimum bandwidth is BW_{Min}) to accommodate the newly arrived call. On the other hand, when a call completes or handoffs to other cells, some of the remaining calls in the cell may be provided an increase in their bandwidth (the maximum bandwidth is BW_{Max}).

The proposed adaptation bandwidth algorithms use different of above ideas to allocate, increase, and decrease bandwidth for the calls in a cell. For accepted arrivals, if there is enough available bandwidth, the algorithm allocates the amount of bandwidth as per the negotiation with the CAC determined by the call. In the vise versa case, some lower priority call's bandwidth will be decreased to their average bandwidth (the average bandwidth is BW_{Avg}) to accommodate the new arrivals.

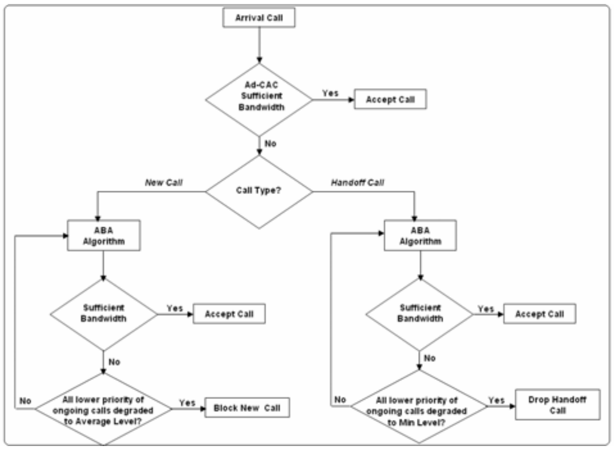

Fig. 2: Call Admission Control Algorithm

In the case of accepted Handoffs, if there is sufficient available bandwidth, the algorithm allocates the amount of bandwidth as per the negotiation with the CAC determined by the call. In the case of a vise versa condition, some lower priority calls' bandwidth will be decreased to lower their bandwidth (the minimum bandwidth is BW_{Min}) to accommodate the new handoffs arrivals. For call departures (call completely terminated or moved to another cell), the available bandwidth within the cell increases, and the algorithm will then selectively increase the bandwidth of some calls in the cell that have higher priority and smallest degradation level. The proposed algorithm known as N-Level-ABA is shown in Fig.3(a) – 3(c).

```
Ad_CAC () {

If (BW_Avail >= BW_Max)
        {
        Allocate (BW_Max, MaxLevel)
        Accept Connection
        }
Else If (BW_Avail >= BW_Min)
        {
        Find the BW_Allocate and BWLevel that can be taken for connection
        (Where BW_Min <= BW_Allocate < BW_Max, MinLevel <= BWLevel < MaxLevel)
        Allocate (BW_Allocate, BWLevel)
        Accept Connection
        }
        Else {
                If (incoming call is new call)
                   DegradeBW (BW_Avg, AvgLevel, Application_Priority)
                Else // incoming call is Handoff call
                   DegradeBW (BW_Avg, MinLevel, Application_Priority)
                If (Success)
                  {
                  Save all degraded on existing calls with new Allocation BW
                  Allocate (BW_Avg, AvgLevel)
                  Accept Connection
                  }
                Else If (BW_Avail >= BW_Min)
                        {
                        Save all degraded on existing calls with new Allocation
                        Find the BW_Allocate and BWLevel that can be taken for connection
                        (Where BW_Min <= BW_Allocate < BW_Avg, MinLevel <= BWLevel < AvgLevel)
                        Allocate (BW_Allocate , BWLevel )
                        Accept Connection
                        }
                  Else
                        {
                        Return all degradation on existing calls with old Allocation BW
                        Block Connection
                        }
            }
        }
```

Fig.3(a): The Adaptive CAC in the N-Level-ABA Algorithm

To support Ad-CAC the ABA algorithm performs two main procedures: degradation and upgrading. The degradation procedure is triggered when an accepted arriving call (new or handoff) arrives to an overloaded cell. The algorithm has been elaborated in Fig. 3(b). The upgrading procedure is triggered when there is an outgoing handoff call or a call completion in the given cell. The algorithm has been elaborated in Fig. 3(c).

Whenever CAC accepts an arrival call being new or handoff, the system attempts to allocate maximum bandwidth (BW_{Max}) for this call. Thus, if the available bandwidth is larger than or equal to the bandwidth requested, the arrival call will be allocated a bandwidth requested.

```
DegradeBW (BW_needed, DegradeLevel, App_Priority)
{
PriorityIndex = 1
While (PriorityIndex <= App_Priority)
        {
        For (LevelIndex = MaxLevel to DegradeLevel)
            {
                If existing call (A-Priorty = PriorityIndex && BWLevel = LevelIndex)
                  {
                  /* degrade the allocate BW by one level */
                  BW_Allocate = BW_Allocate – BW_DegradeLevel
                  BWLevel = BWLevel – 1
                  }
                If (BW_Avail >= BW_needed)
                   Return (Success)
            }
        PriorityIndex = PriorityIndex + 1
        }
        Return (! Success)
}
```

Fig.3 (b): The Bandwidth Degradation in the N-Level-ABA Algorithm

```
UpgradeBW (BW_free)
{
BW_Avail = BW_Avail + BW_free
For (HighPriority to LowPriority)
    {
        If (BW_Avail > 0)
        For (LevelIndex = MinLevel to MaxLevel)
            {
                If (BW_Avail > 0 && BW_Avail >= BW_UpgredeLevel)
                  {
                  /* Upgrade the allocate BW by one level */
                  BW_Avail = BW_Avail - BW_UpgredeLevel
                  BW_Allocate = BW_Allocate + BW_UpgredeLevel
                  BWLevel = BWLevel + 1
                  }
                Else
                  Break
            }
        Else
          Break
    }
}
```

Fig.3(c): The Bandwidth Upgrade in the N-Level-ABA Algorithm

If the available bandwidth is larger than or equal to the minimum bandwidth (BW_{Min}), a negotiation between mobile's call and CAC to get the maximum bandwidth level from available bandwidth that will be allocated for a call is done. Otherwise; a degradation procedure is triggered to degrade the bandwidth of some ongoing calls in the cell to attempt to allocate average bandwidth (BW_{Avg}) as follows. Calls with the largest allocated bandwidth greater than BW_{Avg} and lower or equal priority to arrival call are degraded to have lower bandwidth not less than BW_{Avg}. If the saved bandwidth is larger than or equal to bandwidth requested, the arrival call will allocated a bandwidth requested. Otherwise, further bandwidth degradation to accommodate the call cannot be performed. If the saved bandwidth is larger than or equal to BW_{Min}, the arrival call will be allocated a bandwidth not less than the minimum bandwidth. If all above tests is not complied with, then blocking of arrival call is done. But a handoff call system attempts to allocate BW_{Avg} for this call. Thus, if the available bandwidth is larger than or equal to bandwidth requested, the handoff call will be allocated a bandwidth requested. Or, if the available bandwidth is larger than or equal to BW_{Min}, a negotiation between mobile's call and CAC to get the maximum bandwidth level from available bandwidth that will be allocated for a call. In any other case a degradation procedure is triggered to degrade the bandwidth of some ongoing calls in the cell to attempt to allocate BW_{Avg} as follows. Calls with the largest allocated bandwidth greater than BW_{Min} and lower or equal priority to handoff call are degraded to have lower bandwidth not less than BW_{Min}. If the saved bandwidth is larger than or equal to the bandwidth requested, the handoff call will be allocated the bandwidth requested. Non compliance to this situation will prevent the possibility of further bandwidth degradation to accommodate the call. If the saved bandwidth is larger than or equal to BW_{Min}, the handoff call will be allocated a bandwidth not less than the minimum bandwidth. If all above tests fail, then the dropping of the handoff call is done. As a call leaves the cell, whether outgoing handoff call or a call completion, the total available bandwidth increases. The system will invoke the bandwidth upgrading procedure to increase the bandwidth for one or more of the degraded calls to the bandwidth requested, starting from higher priority and the most degraded calls in the cell. The upgrading procedure is terminated when there is no available bandwidth or every call in the cell has a bandwidth larger than or equal to bandwidth requested.

The modeling of the Ad-CAC in the contexts of the respective entities and their relationships require a detail correlation between the elaborated components. The correlation is between the mobiles, the traffic profile and the proposed algorithms in Fig. 3(a)…3(c). During a call setup, a mobile running a user multimedia service defines its requirements in a traffic profile. The traffic profile is then sent to the Ad-CAC management component to determine the acceptance or rejection of the call based on the following parameters: traffic type, number of ongoing calls and the amount of available bandwidth in the system. Subsequently, the Ad-CAC decides whether an incoming call is accepted in a cell or not.

In determining the acceptance of a call, two mechanisms are deployed. First, when the wireless bandwidth is underutilized, all incoming calls are admitted. Secondly, when the bandwidth is fully utilized, only new high priority calls will be admitted, while ongoing lower priority calls would be degraded. Let us denote M_i as the number of class i new connections and let us denote N_i as the number of class i handoff that are present in the system at the time of call request., BW_{NC_i}, is denoted as the total bandwidth allocated for class i new connections and let us denote BW_{H_i}, as the total bandwidth allocated for class i handoff connections. The computation of the respective parameters are deliberated from Equation (1…7)

$$BW_{NC_i} = \sum_{j=1}^{M_i} BW_{i,Allocated_j} \tag{1}$$

and

$$BW_{H_i} = \sum_{j=1}^{N_i} BW_{i,Allocated_j} \tag{2}$$

Let us denote C as the total capacity bandwidth of the cell, then the available bandwidth $BW_{Avil,}$ is given by

$$BW_{Avil} = C - \sum_{i=1}^{k} (BW_{NC_i} + BW_{H_i}) \tag{3}$$

Let us denote $BW_{Degraded\text{-}Avg_i}$, as the total bandwidth that can be degraded to BW_{Avg} for class i and denote $BW_{Degraded\text{-}Min_i}$, as the total bandwidth that can be degraded to BW_{Min}

$$BW_{Degraded-Avg_i} = \sum_{j=1}^{M_i+N_i} (BW_{i,Allocated_j} - BW_{Avg_i}) \forall j \quad BW_{i,Allocated_j} \geq BW_{Avg_i} \tag{4}$$

and

$$BW_{Degraded-Min_i} = \sum_{j=1}^{M_i+N_i} (BW_{i,Allocated_j} - BW_{Min_i}) \tag{5}$$

A new call of class i with priority p is accepted if

$$BW_{needed_{i,p}} \leq BW_{Avil} + \sum_{j=1}^{p} (BW_{Degraded-Avg_j}) \tag{6}$$

A handoff call of class i with priority p is accepted if

$$BW_{needed_{i,p}} \leq BW_{Avil} + \sum_{j=1}^{p} (BW_{Degraded-Min_j}) \tag{7}$$

A newly arriving call of class i with priority p is blocked if its needed bandwidth is greater than bandwidth available plus total current bandwidth that can be degraded to BW_{Avg} of ongoing connections that have lower or equal p of new arriving call. For, a handoff arriving call of class i with priority p is dropped if its needed bandwidth is greater than bandwidth available plus total current bandwidth that can be degraded to BW_{Min} of ongoing connections that have lower or equal p of handoff arriving call.

4. Simulation model

A discrete-event simulation model for a wireless cellular network environment in a two-dimensional (2-D) topology in which each cell has exactly six neighboring cells is extensively developed using C++. The simulated area consists of 64 Omni-cells and has a uniform geographic distribution. It is assumed that a base station is located in the center of a hexagonal. The cell radius is set to 200m while the handoff region set to 10m.The cells are wrapped around so the topology of the simulated environment represents a sphere and making the handoff rates in all the cells is approximately similar. Data sources are assumed to be of bursty nature. Connections requests are generated according to a Poisson process with rate ë (connections/second/cell) in each cell of different the traffic classes. A newly generated connection can appear anywhere in the cell with an equal probability. The call duration for each mobile is exponentially distributed with rates equal to µ. In order to represent various multimedia applications, six different application groups are assumed based on the connection duration, bandwidth requirement and class of service. The classification strategy is adopted from [21-23]. The different application groups include Constant Bit Rate (CBR), Variable Bit Rate (VBR), and data traffic sources (Unspecified Bit Rate-UBR). The six application groups are carefully chosen for a simulation; they are typical traffic seen in wireless networks and their respective parameter values are chosen from Table 1. The value closely represents realistic scenarios. It is assumed the system uses Fixed Channel Allocation (FCA). No matter which multiple access technology (FDMA, TDMA, or CDMA) is used, we could interpret system capacity in terms of effective or equivalent bandwidth [24]. Hereafter, whenever the bandwidth of a call is referred to, the meaning is denoted as the bandwidth level that is adequate for guaranteeing desired QoS for this call with certain traffic characteristics. A cell that has a maximum bandwidth capacity for each base station is set to 30 Mbps. Two types of calls share the bandwidth of the cell: new calls and handoff calls. The bandwidth required for VBR and UBR is assumed to follow a geometrical distribution between the minimum and maximum values shown in the Table 1. The connection duration is also assumed to follow a geometric distribution between the minimum and maximum values shown in the table. New connections from all the six application groups are generated with equal probability.

Table 1: Traffic Characteristics

Traffic Type-Class No.	Type of Media	Bandwidth Requirements			Duration of connection			Priority
		Min.	Avg.	Max.	Min.	Avg.	Max.	
CBR-1	Voice service and audio phone	30 Kbps	30 Kbps	30 Kbps	1 min	3 min	10 min	6
CBR-2	Video-phone and video-conference	256 Kbps	256 Kbps	256 Kbps	1 min	5 min	30 min	5
VBR-3	Interactive multimedia and video on demand	1 Mbps	3 Mbps	6 Mbps	5 min	10 min	300 min	4
UBR-4	Email ,paging and fax	5 Kbps	10 Kbps	20 Kbps	10 sec	30 sec	2 min	3
UBR-5	Remote login and data on demand	64 Kbps	256 Kbps	512 Kbps	30 sec	3 min	10 hour	2
UBR-6	File transfer and retrieval service	1 Mbps	5 Mbps	10 Mbps	30 sec	2 min	20 min	1

Three parameters for mobility model are considered, the initial position of a mobile, its direction and its speed. A newly generated call can appear anywhere in the cell with an equal probability. When a new call is initiated, a mobile is assigned a random initial position derived from a uniform probability distribution function over the cell area. To determine the cell coverage and Handoff region threshold, the propagation model proposed by [25-26] is adopted where the received signal strength, RSS from a particular cell to celli, can be expressed as

$$RSS = -10\gamma \times \log(d_i) \tag{8}$$

Where γ is the propagation path-loss coefficient (typically, γ = 2 for highways and γ = 4 for micro-cells in a city) and di represents the distance (of the transmitter to the mobile) between the mobile and base station of celli, which can be further expressed in terms of the mobile's position (x(t), y(t)) at time t and the location of base station (ai, bi)

$$d_i = \sqrt{(x(t)-a_i)^2 + (y(t)-b_i)^2} \tag{9}$$

The mobile coordinate position can be used to determine the location of a mobile in the cell. When the base station detects that a mobile has entered the handoff region (by comparing its RSS with certain threshold), the current base station sends a bandwidth request to the new base station (one of the neighboring cells of current cell) that the mobile is heading to is determined in order to pre-allocate a bandwidth for expected handoff event. The representation of coverage region and handoff region is shown in Fig. 4. A mobile can travel in one of six directions with equal probability. As for handoff calls, the initial position is determined when the handoff event is done. A mobile is assigned a random direction upon entering a cell. A constant randomly selected speed is assigned to a mobile when it enters a cell either at call initiation or after handoff.

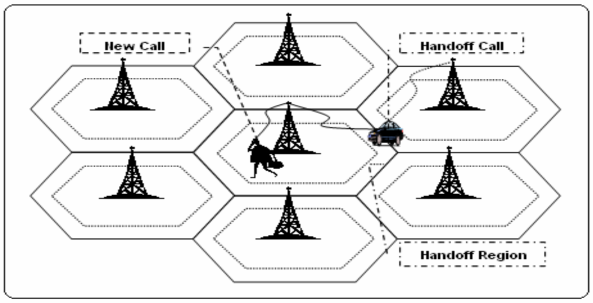

Fig. 4: Coverage and Handoff Region

The speed of the mobile is obtained from a uniform probability distribution function ranging between 10Vmin and 60Vmax. The system interval for checking the location of mobile is assumed to be performed every 5 m.

5. Result and Discussion

The performance of the proposed scheme is discussed in this section. The algorithm is assessed in its ability to provide adaptive QoS as compared to a non-adaptive scheme. The non-adaptive scheme is simulated assuming that a call must be allocated its maximum bandwidth to be admitted and once accepted its bandwidth cannot be changed throughout the lifetime; if such bandwidth is not available, the call is either blocked or dropped depending on whether the call is a new or handoff call. The selected non-adaptive scheme is from [27-28]. Each base station in the non-adaptive scheme is allocated a reservation target (R_{Target}) that is updated periodically according to the projected demands of anticipated handoffs from neighboring cells (incoming from neighboring cells and outgoing from the cell). A new call is accepted if the remaining resource after it acceptance is at least R_{Target}. For handoff call, the admission control rule is more lenient: it is admitted as long as there is sufficient remaining capacity to accommodate the handoff, regardless of value of R_{Target}.

The performance metrics utilized encompasses two QoS parameters: new call blocking probability (NCBP) and handoff call dropping probability (HCDP). The bandwidth utilization is also measured to illustrate the ability of the system to maintain efficient bandwidth utilization while attempting to strike a balance between these two QoS parameters (NCBP and HCDP). The system performance is evaluated with and without the effect of the bandwidth reallocation algorithm on the NCBP, HCDP and bandwidth utilization. In each cell, the BS is responsible for connection setup, CAC, call termination, bandwidth reallocation and bandwidth reservation for new and handoff calls. In most of the simulation results that follows, the performance measures are plotted as a function of the connection arrival rate. The connection arrival rate is the arrival rate of new connections measured as the average number of new connection requests per second per cell.

The impact of the traffic nature is analyzed as an indicator of the differentiated services need. The first scenario analyzed is the uniform traffic. The uniform traffic distribution in the simulations, where the traffic load is the same among all 64 cells is utilized. Call arrivals of classes to each cell follow a Poisson process with mean ë .the effect of equal traffic loading in different cells can be shown in figures

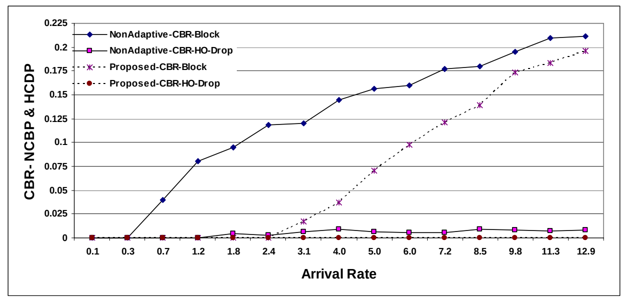

Fig. 5: Real time (CBR) - NCBP and HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

Fig. 5-8, depicts the NCBP and HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services, respectively. Clearly, the NCBP performance for adaptive multimedia is better than that for non-adaptive multimedia due to the CAC scheme and the bandwidth adaptation algorithm employed. The result indicates that the HCDP for adaptive multimedia and non-adaptive multimedia services is near zero under low traffic loads. This is trivially true by the nature of the algorithm as per our discussion in earlier sections. However, if the traffic is very heavy, HCDP is non-zero. For non-adaptive multimedia, HCDP is significant even under low traffic loads.

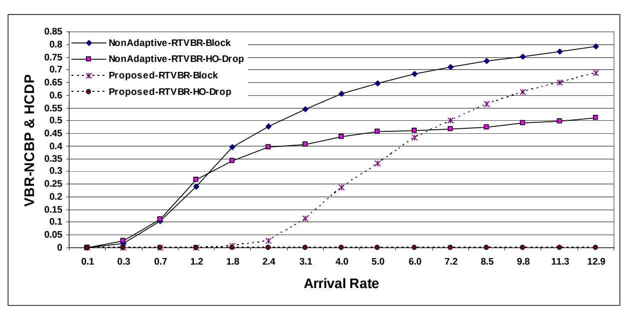

Fig. 6: Real time (VBR) - NCBP and HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

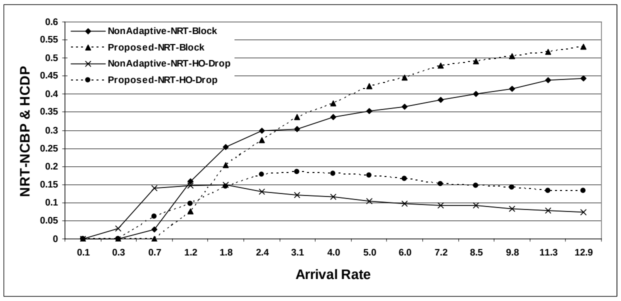

Fig. 7: Non real time (UBR) - NCBP and HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

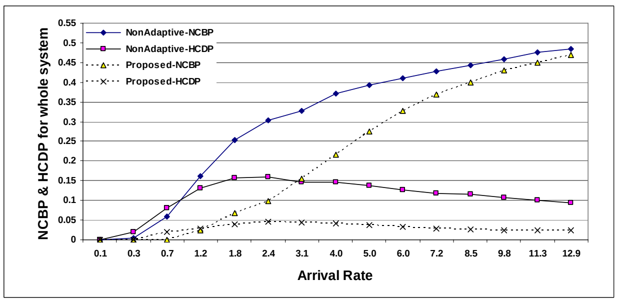

Fig. 8: NCBP and HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

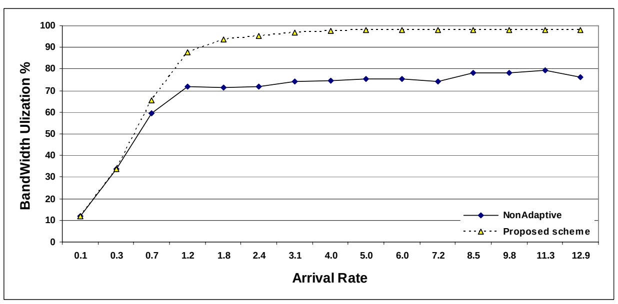

Fig. 9: Bandwidth Utilization versus the traffic load for adaptive multimedia and non-adaptive multimedia services

Figure 9 shows the utilization versus the traffic load for adaptive multimedia and non-adaptive multimedia services. Clearly, the utilization for adaptive multimedia is better than that for non-adaptive multimedia. When the traffic load becomes higher, the advantage is more evident. The reason for multimedia services' better resource utilization is due to the very adaptive nature of these services that allows the network to offer services whenever there is sufficient amount of resources by intelligently adjusting resource allocation. Also, NL-ABA offers more flexibility of bandwidth adjustment, thus resulting in better resource utilization.

In summary, from a service provider's point of view, the proposed methods outperform the non-adaptive multimedia services in terms of utilization, NCBP and HCDP while QoS requirements are satisfied. One reason for this is that we allow the multimedia service to be adaptive in order to mitigate the fluctuation of the system resources. Other reasons, such as the CAC scheme chosen and the bandwidth adaptation algorithm used also play very important roles. On the other hand, from a service user's point of view, QoS is improved by adopting new QoS parameters to effectively characterize the bandwidth degradation caused by adaptation.

The second scenario analyzed is the non-uniform traffic. In the non-uniform traffic situation, the cells that have even id number, i.e., cells 2, 4, 6,…, 64, have 2 times the new call arrival rate of those cells in that have odd id number , i.e., cells 1, 3,5,…,63. The effect of non-equal traffic loading in different cells is shown in figures 10…14. If different cells have non-equal traffic loading, some cells should use more bandwidth than others for accommodating a heavier call arriving rate. It is possible that some cells can run out of resource (bandwidth capacity). To solve this problem, we can adopt the concept channel borrowing mechanism. Channel borrowing mechanism states that the whole capacity of any cell is not a fixed value. Each cell only keeps a set of nominal channels and can borrow free channel from its neighboring cells to accommodate new calls. Through the using channel borrowing mechanism, the NCBP can be further decreased. One of our future tasks is combining the channel borrowing mechanism with our proposed approach to investigate the improvement of NCBP.

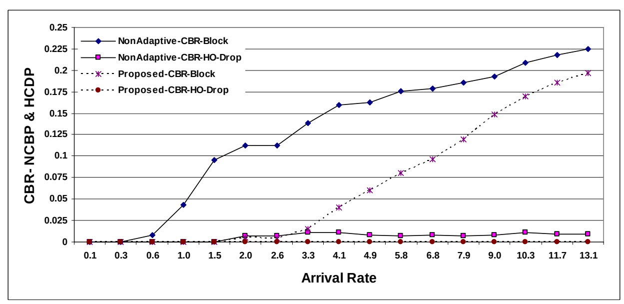

Fig. 10: Real time (CBR) - NCBP-HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

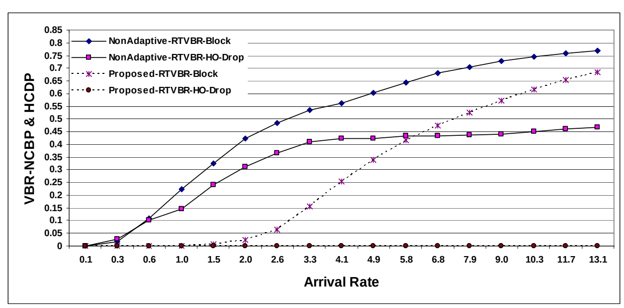

Fig. 11: Real time (VBR) - NCBP-HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

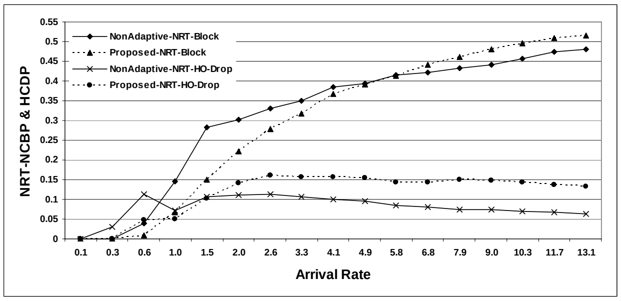

Fig. 12: Non real time (UBR) - NCBP-HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

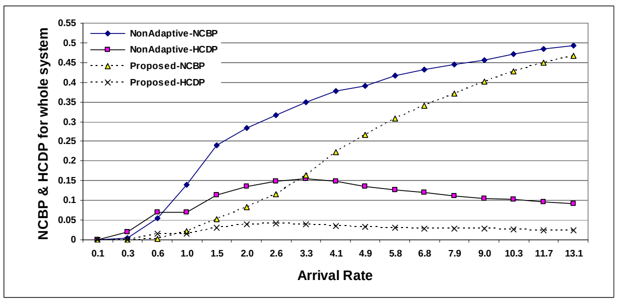

Fig. 13: NCBP-HCDP versus the traffic load for adaptive multimedia and non-adaptive multimedia services

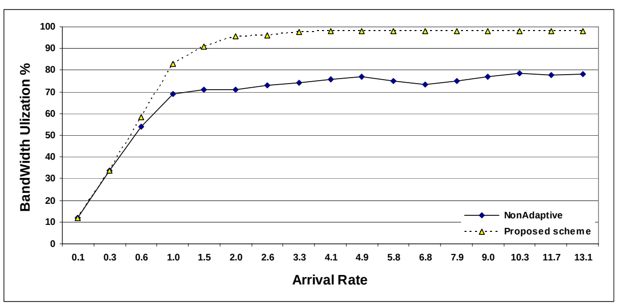

Fig. 14: Bandwidth Utilization versus the traffic load for adaptive multimedia and non-adaptive multimedia services

6. Conclusion and Future Research

In this paper, a novel Adaptive Call Admission Control (Ad-CAC) framework for wireless cellular networks is proposed. The proposed framework considers different traffic type with multiple classes of wireless multimedia services with different QoS requirements. Complementary to these traffic types, an adaptive Admission Control which enables a versatile computation of bandwidth allocation. The versatility is provided by multi-level negotiations thresholds that permit higher utilization of bandwidth while trading of QoS degradation. Three related components comprise the main building blocks of the framework: (i) a bandwidth reallocation policy, (ii) an Adaptation bandwidth allocation module, and (iii) an admission controller module. The underlying goals of our Ad-CAC framework are achieved simultaneously. The acquired results justifies the ability of the adaptive multimedia framework significantly outperforms the non-adaptive multimedia services. The findings are hence a pioneering nature as it is the first to simultaneously address these issues. Simulation results show that the system is able to guarantee the connection-level QoS handoff call dropping probability for each class of traffic. Thus, it satisfies mobile users' needs resulting in a stable performance levels during heavy load periods. Furthermore, the Ad-CAC provides a low call blocking probability of new calls, which translates into high resource utilization. This is a highly desirable property from the service provider point of view. The overall performance of the adaptive multimedia networking is very attractive in that the handoff call dropping probability is near zero (negligible) and that the effective utilization increases as the offered traffic load increases. We argue that this work is a powerful and novel contribution in wireless/mobile cellular network design as it can be used to support high bandwidth multimedia applications in a manner that enhances the overall system performance. In addition, our framework is cell-oriented, meaning that all its components are implemented on a cell-by cell basis. It thus has an extremely low complexity making it practical for real wireless/mobile cellular networks.

The efficiency of the proposed algorithms will be further enhanced through an integration of the prediction algorithms which are linked with the mobility and signal strength.

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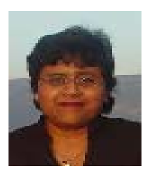

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