Radio Resource Management Issues for 3G and Beyond Cellular Wireless Networks

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Abstract— **Radio resource management (RRM) in the next generation wireless network system will have features and requirements that are quite distinct from current systems, mostly designed for non-heterogeneous and non-shared networks. Such features include radio resource sharing which is considered as one of the main future issues of RRM as network evolves towards 4G. Radio resource sharing has an impact on system design in general and on radio resource management in particular. This paper presents a general RRM for 3G and beyond mobile wireless network supporting multi-services, referred to as general call admission control (GCAC). The aim of the proposed GCAC algorithm is to guarantee the required quality of service (QoS) and to maintain higher resource utilization. Simulation results indicate that the proposed GCAC provides higher resource utilization under all load conditions leading in turn to increased revenue. In addition, a higher quality of service for traffic is provided especially when we differentiate between the traffic classes.**

Index Terms **— Admission control, Multi-Operator, Queuing, RRM, WCDMA, 3G.**

I. INTRODUCTION

RRM in the next generation wireless access system will have features and requirements that are quite distinct from current systems, mostly designed for non-heterogeneous and non-shared networks. Such features include radio resource sharing which is considered as one of the main future issues of RRM as network evolves towards 4G. These features have an impact on system design in general and on radio resource management in particular. In general, radio resources of 3G and beyond are managed using various schemes that can be grouped in three main sets. The first set includes frequency/time resource allocation schemes such scheduling. The second set consists of power allocation and control schemes, which control the transmitter power of the terminals and the base stations. The third set comprises call admission control, and base station (BS) assignment (Fig. 1) [12]. All these managing schemes constitute the RRM controllers which take the current cell loading, channel condition, and radio resource sharing into consideration.

A number of proposals have been put forward that involve the sharing of network resources, ranging from the sharing of base station equipment to roaming onto other operators networks in areas where coverage has not yet been supplied [1-7]. The main emphasis of these proposals is to reduce the cost of achieving nationwide coverage and thus speed up the transfer from 2G to 3G and to 4G. With roaming based sharing, as one of the RAN sharing options, an operator accesses the other operators' radio access network (RAN) indirectly via the core network. This implies that multiple operators fully share the same RAN, and therefore there is a critical need for radio resource control between the multiple operators. A number of these proposals do however have implications for RRM. RRM must be enhanced to be able to provide the required QoS among users belonging to more than one operator and sharing the same radio resource.

The key to RRM in future networks will be in examining and analyzing the types of changes that are required for existing algorithms to be efficiently implemented in the evolving 3G and beyond networks. QoS based CAC and radio resource sharing strategies among one or multi-operators 3G is one of the crucial components of RRM. The focus of this paper is the design and evaluation of a general call admission control (GCAC) which is the key elements of RRM for 3G and beyond mobile wireless network supporting multi-services. The aim of the proposed GCAC algorithm is to guarantee the required quality of service (QoS) and to maintain higher resource utilization.

Service Level Agreements (SLA) specifies how the usage of the radio network capacity for each operator under the roaming-based sharing agreement. Each operator receives the agreed upon QoS level by following the specified operation rules in the SLA [7]. In order to optimize the usage of the allotted capacity, GCAC can be divided into two main levels.

- *Level 1*: is to maintain the admission priority among different classes of one sharing operator.
- *Level 2*: is to maintain the cell resource sharing among different operators sharing the same RAN.

Several uplink CACs designed for 3G WCDMA have been proposed in the literature [8-12]. These CACs can be classified based on the admission criterion into the following four categories: power based CAC, throughput based CAC, interference based CAC, and SIR based CAC. For power based CAC algorithms the total received power is monitored, while throughput based CACs monitor the system load. Interference based CAC algorithms monitor the total received interference, and SIR based CACs monitor the SIR figure experienced by every user. Most of these schemes did not differentiate between different type of traffic based on call type and traffic class. More over they did not consider buffering techniques for traffic classes. Two methods for controlling resource sharing in a roaming-based scenario were proposed in [1] and [2]. These methods include, *Complete Partitioning (CP) scheme* where a fixed capacity share is allocated for each operator and *dynamically prioritized operators* where the priority for an operator's traffic is dynamically determined by its current usage of the shared capacity.

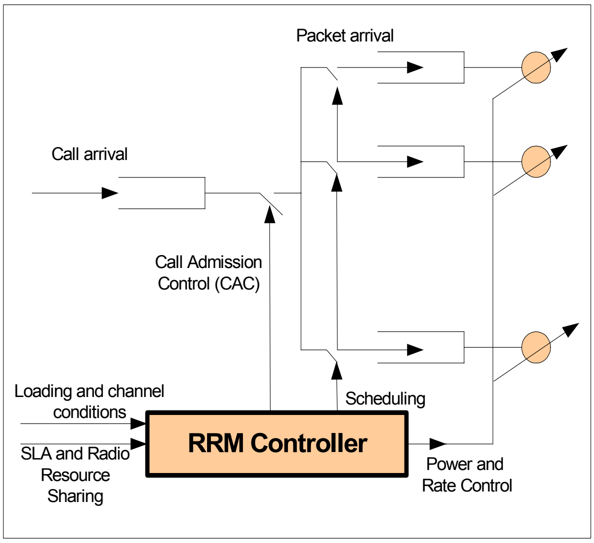

Fig. 1: General RRM Model.

II. SYSTEM MODEL

The system under consideration is a 3G WCDMA cellular network supporting heterogeneous traffic. The capacity of WCDMA cell is defined in terms of the cell load [12] where the load factor, η, is the instantaneous resource utilization upper bounded by the maximum cell capacity, $\eta_{\max}$. Instantaneous values for the cell load η range from 0 to 1. While the proposed algorithm is directly applicable for any number of coexisting operators, the analysis and evaluation below is carried for the case of two operators assuming that the assigned soft capacity based on the SLA for operator j is given by η_j, where j = 1, 2, such that

$$\eta_1 + \eta_2 \le \eta_{\max} \quad (1)$$

Furthermore, the study assumes each operator supports two classes of services: real-time services such as voice and non-real time services such as WWW data traffic. The incoming call requests are divided into four types. These types are: 1) newly originating real-time calls; 2) newly originating nonreal-time calls; 3) real-time service handoff requests; and 4) nonreal-time service handoff requests. Handoff requests have higher priority over new calls and the real-time service handoff requests have the highest priority. Handoff requests for voice and data calls for each operator have their own queues: Q1 and Q2, with finite capacities K and L, respectively. A handoff request of an operator is placed in its corresponding queue if it cannot be serviced upon its arrival. The algorithm first tries to accommodate every incoming request using the allocated capacity for the respective operator. The proposed GCAC consists of two main levels. Level 1 is to control the admission of each operator and called call admission control (CAC). Level 2 is to control the admission control among more than one operator and called muli-operator admission control (MOAC). Fig. 2 shows a schematic diagram of the proposed GCAC algorithm.

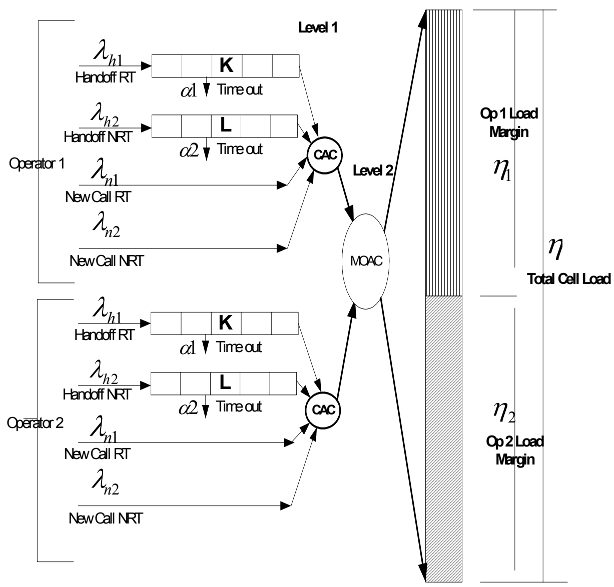

Fig. 2: Proposed GCAC model.

III. GCAC ALGORITHMS

The developed GCAC algorithm attempts to achieve two main functions: first the management of resource allocation amongst the different operators, and secondly, to perform the call admission control for each operator while satisfying the QoS requirements. Only the uplink direction is considered this study where it is assumed that whenever the uplink channel is assigned the downlink is established. To implement the admission control for WCDMA systems, first an estimate of the total cell load must be computed to be employed in the decision process of acceptance or rejection of new connections. In addition, the analysis assumes perfect power control operation where a mobile station (MS) and its home base station (BS) use only the minimum needed power in order to achieve the required performance. Considering the interference on the uplink, the load factor increment □□$_i$ for a new request i can be estimated as [12];

$$\Delta\eta_i = \frac{1}{1 + G_i/\rho_i} \qquad (2)$$

where $G_i = W/R_i$ is the processing gain for the i^{th} MS, R_i is the bit rate associated with the i^{th} MS, and W is the chip rate of the WCDMA system. □$_i$ is the bit-energy to noise-density figure corresponding to the desired link quality. Using the load factor increment definition, the total load factor, η, of such an interference system is the sum of the load factor increments brought by N active mobile users. Therefore,

$$\eta = \sum_{i=1}^{N} \Delta\eta_i = (1+f)\sum_{i=1}^{N} \frac{\nu_i}{1 + G_i/\rho_i} \qquad (3)$$

where f is the factor accounting for interference from other cells and is defined as the ratio of inter-cell interference to the total interference in the referenced cell, whereas ν_i is the average traffic activity factor of user i. Below we define the admission levels: Level 1 and Level 2.

A. Level 2: MOAC

The admission priority or decision among more than one operators call is based on the resource sharing strategy used. for the case of CP allocation, each operator's share η_j defines the maximum capacity level per cell for j^{th} operator without any sharing. Hence, each operator's call admission control procedure works independently. In case of DP allocation, all cell load, $\eta_{\max}$, is open for all operators operator

B. Level 1: CAC

In CAC, the arrived call is queued in its corresponding queue, i.e. depending on its class, if no resource available upon its arrival. Class 1 calls are admitted as long as there is any free resource based on MOAC decision (i.e, as long as current loading factor is below the maximum). In case of CP, all calls are admitted only when there is sufficient capacity per operator. Therefore the call admission criterion is given by

$$\eta_{c.j} + \Delta\eta_{i,j} \le \eta_j \qquad (4)$$

In case of DP, all calls are admitted only when there is sufficient capacity per cell. Therefore the call admission criterion is given by

$$\eta_{c.j} + \Delta\eta_{i,j} \le \eta_{\max} \qquad (5)$$

where $\eta_{c.j}$ is the current uplink load for operator j and $\Delta\eta_{i,j}$ is the increment load required by the arrival call of class i of operator j.

When all resources are occupied (rejected by MOAC) , then after releasing a resource the next call to be served is the one with highest priority non-empty queue, i.e. the lower class index. Any call class is deleted from its queue if it exceeds the queuing time limit.

V. SIMULATION RESULTS

A. Traffic Model

The arrival process of new and handoff calls is Poisson with rates, $\lambda_{h1,j}$, $\lambda_{h2,j}$, $\lambda_{n1,j}$, $\lambda_{n2,j}$, , for RT handoff call , NRT handoff calls, RT new calls and NRT new calls of operator j, respectively. The channel holding time for each type of calls of operator j is exponentially distributed with mean u_j^{-1} while the queuing time of each calls class is exponentially distributed with mean γ_j^{-1}.The total offered load per operator j is denoted l_j, and it is defined as

$$l_j = \mu_j^{-1}(\lambda_{h1,j} + \lambda_{h2,j} + \lambda_{n1,j} + \lambda_{n2,j}) \qquad (6)$$

The total offered load to the whole system then is given by

$$l = \sum_{j=1}^{B} l_j \qquad (7)$$

where B is the number of operators sharing the network

B. System Performance Measures

Algorithms are evaluated based on two metrics: Grade of Service (GoS) and the system utilization or carried traffic (CT). The Grade of service is defined as:

$$GoS_j = \alpha * P_{hb,j} + P_{nb,j} \qquad (8)$$

where $P_{hb,j}$ is the handoff blocking probability, and $P_{nb,j}$ is the new call blocking probability of calls belonging to operator j. $\alpha = 10$ indicates priority level for handoff call relative to a new call. Smaller GoS means better system performance. The total carried traffic of operator j is defined as:

$$\begin{aligned} CT_j &= \lambda_{h1,j}(1-P_{h1,j}) + \lambda_{h2,j}(1-P_{h2,j}) \\ &+ \lambda_{n1,j}(1-P_{n1,j}) + \lambda_{n2,j}(1-P_{n2,j}) \end{aligned} \qquad (9)$$

C. Simulation Parameters

The parameters for the traffic types used in this simulation are as specified in Table 1 while the physical layer parameters for the WCDMA network are as specified in Table 2.

Table 1: Characteristic of two classes' services.

Service Class	Bit rates (Kbps)	Required Eb/No(dB)	Activity Factor
RT-voice	12.2	5	0.4
NRT	64,128,384	3.5,2.5,2.0	1

Table 2: Simulation Parameters for the networks.

Parameter	Value
Radio Access Mode	WCDMA (FDD) Uplink With perfect power control
Chip-rate	3.84Mbps
Thermal noise	1.0 e-15 W
Dedicated channel rates	12.2, 64, 128, 256, 384 Kbps
Max cell load	80% of pole capacity
Operators 1 and 2 load	40% each
Call Duration, queuing time	Exponential (100 sec, 15 sec)
Handoff Calls Queue size	5
Call Arrival	Poisson

D. Result Discussions

In this section we focus on the evaluation of the proposed GCAC algorithm with respect to two metrics: the supported GoS, carried traffic and the provided bandwidth utilization gained by the operators. The latter metric is directly proportional of potential revenue and therefore it a concern for operators

To characterize the performance of the level 1 CAC scheme, we vary the offered load for one operator and evaluate the corresponding GoS and carried traffic for RT and NRT. The GoS for RT (i.e., voice) traffic and NRT (i.e., data) traffic are as shown in Fig. 3 and Fig. 4. As shown in these figures, using buffering and traffic differentiations have positive impact on lowering the GoS for both RT and NRT traffic. Lowering GoS will increase the carried traffic of the operator as shown in Fig. 5.

Examining the total cell utilization when more than one operator share the same cell, we fixed the offered traffic of OP2 and we varied OP1 and we applied the CP and DP allocation schemes. Fig. 4 shows that resource utilization with DP is always higher compared to that offered by CP for all offered loads. This in turn translates to higher revenue for the operator.

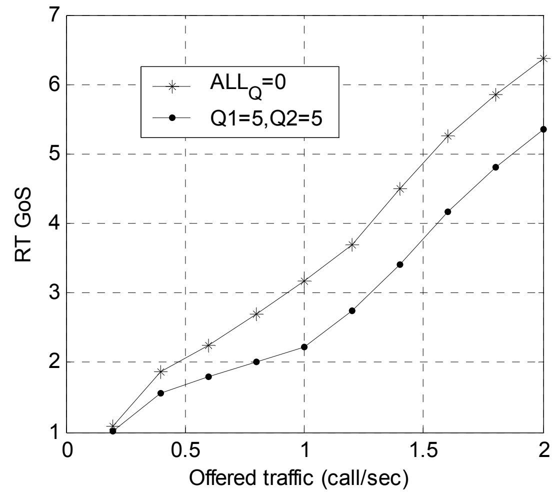

Fig. 3: GoS of the RT calls.

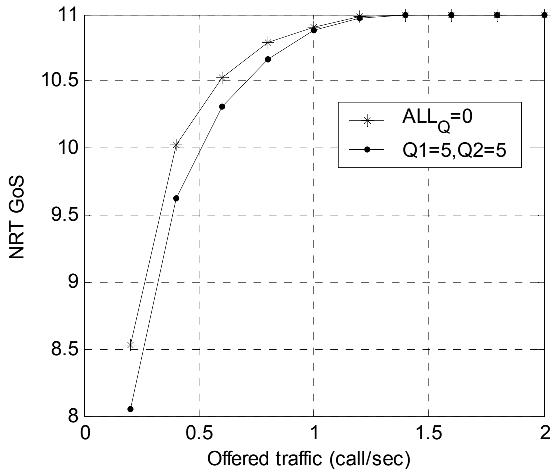

Fig. 4: GoS of the NRT calls.

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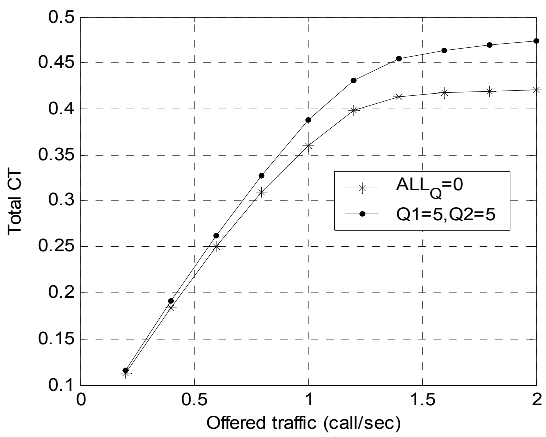

Fig. 5: Total CT of the system

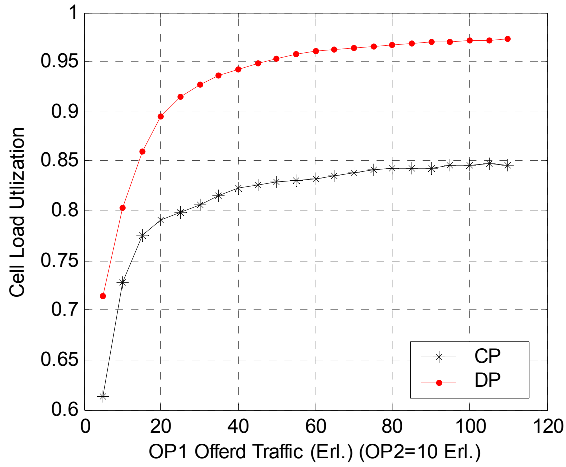

Fig. 6: Total system utilization using CP and DP schemes.

VI. CONCLUSION

This paper presented a general call admission control (GCAC) that can be used for multi-operators RAN sharing in 3G and beyond. The algorithm is designed to provide a high quality of service for multimedia traffic where different traffic types require different proportions of the radio resource. This in turn leads to increased resource utilization for the corresponding operator which translates to higher revenue. Furthermore, CAC makes a distinction between newly originating calls and handoff calls by assuming a higher priority level for handoff calls in the form of possibility of queuing. Therefore, the prescribed call admission control scheme provides a higher quality of service for the handoff requests of real-time services expected in 3rd and 4th G WCDMA systems.

ACKNOWLEDGMENT

The authors acknowledge King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia for support.

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