Call Admission Control Schemes in Non-Cellular Wireless Network

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Abstract

Radio resource management (RRM) plays a major role in Quality of Service (QoS) provisioning for wireless communication systems. The performance of RRM techniques has a direct impact on each user's individual performance and on the overall network performance. Arriving (new and handoff) calls are granted/denied access to the network by the call admission scheme (CAC) based on predefined criteria, taking the network loading conditions into consideration. This article provides an overview of CAC schemes in special wireless networks, namely, satellite systems, multi-hop/ad-hoc networks, high altitude aeronautical platform station, and hierarchical cellular structure.

Sommaire

La gestion des ressources radio (GRD) joue un rôle majeur dans la fourniture de Qualité de service (QS) pour les systèmes de communication sans fil. La performation des techniques de GRD a un impact direct sur la performance de chaque usager et celle du réseau globalement. Les appels entrants (nouveaux ou transferts intercellulaires) voient leur accès au réseau accordé/refusé par le processus d'admission d'appel (PAA) basé sur des critères prédéfinis, prenant en compte les conditions de charge du réseau. Cet article fournit un aperçu des PAA dans des réseaux sans fil spéciaux tels les systèmes satellites, les réseaux ad-hoc/à plusieurs bonds, les plateformes de stations aéronautiques en haute altitude, et les structures cellulaires hiérarchiques.

1.0 Introduction

Radio resource management (RRM) plays a major role in the Quality of Service (QoS) provisioning for wireless communication systems. As a matter of fact, RRM policies along with the network planning and air interface design determine the QoS performance at the individual user level and the network level as well. RRM techniques encompass frequency and/or time channels, transmit power, and network access in order to control the amount of the assigned resources to each user with the objective of maximizing some function such as the total network throughput, total resource utilization or total network revenue subject to some constraints such maximum call blocking/dropping rate (P_b/P_d) and/or minimum signal to interference ratio (SIR). The performance of RRM techniques has a direct impact on each user individual performance and on the overall network performance. For instance, the allocated transmitter power for a user not only determines the QoS offered to this user but it also affects the interference level that other users receive, and as a result it influences the signal quality of other users.

Radio resources are managed using various schemes that can be grouped in three sets. The first set includes frequency/time resource allocation schemes such as channel allocation, scheduling, transmission rate control and bandwidth reservation schemes. The second set consists of power allocation and control schemes, which control the transmitter power of the terminals and access points. The third set comprises call admission control and network access schemes.

As shown in Fig. 1, arriving calls are granted/denied access to the network by the call admission scheme (CAC) based on predefined criteria taking the network loading conditions into consideration. Traffic of admitted calls is then controlled by other RRM techniques such as scheduling, power control and transmission rate control.

CAC has been extensively studied in wireline networks as an essential tool for congestion control and QoS provisioning. Different aspects of CAC design and performance analysis particularly in the context of broadband integrated service digital network (B-ISDN) based on asynchronous transfer mode (ATM) technology have been investigated in [1]. However, the problem of CAC in wireless networks is more sophisticated due to the unique features of wireless networks such as channel multiple access interference, channel impairments, handoff requirements, and limited bandwidth.

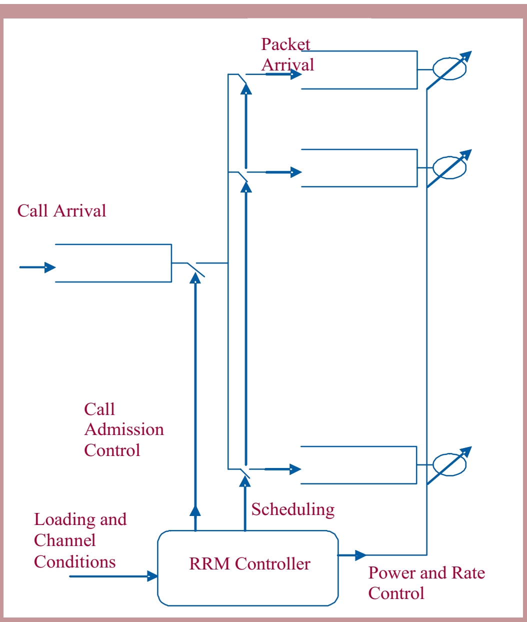

Figure 1: Radio Resource Management Model

CAC schemes developed for cellular wireless networks including second and third generation systems are extensively studied in the literature. Reference [2] includes a comprehensive survey on CAC on wireless cellular networks. This article provides an overview of CAC schemes in special wireless networks, namely, satellite systems, multi-hop/ad-hoc networks, high altitude aeronautical platform station, and hierarchical cellular structure.

2.0 CAC in Satellite Networks

Satellite systems are considered as a complement of terrestrial wireless networks to extend the coverage to large areas with small user density or to areas that can't be covered by terrestrial infrastructure such as large water areas. Satellite systems are also considered for overlapping with terrestrial wireless networks to provide service for high mobile users. However, two main challenges have to be tackled in satellite systems. The first challenge is the large propagation delay that limits the adaptation capability of RRM techniques including CAC schemes. The second challenge is the spectrum partitioning between terrestrial and satellite systems.

In [3], a hybrid system consisting of satellite and cellular coverage is considered. CAC is employed to manage the assignment of arriving calls (new and handoff) to one of the two layers depending on the call type. The admission decision is probabilistic where the admission probability is chosen to minimizes the blocking probability subject to constraints on the dropping probability and average percentage of calls assigned to the satellite coverage given a certain bandwidth partitioning plan. The second constraint is used to represent the consideration of the large propagation delay in the satellite connection. Ordinal optimization, which is a simulation-based optimization technique [4], is used to find the optimum CAC policy which is shown to outperform two known policies, namely, cellular first (CF) and satellite first (SF).

A threshold-based CAC scheme has been proposed in [5]. Call admission is based on resource availability for constant bit rate (CBR), bursty data, and best effort services using double movable boundary strategy for resource sharing over the satellite uplink. The threshold values are adaptive and depend on the traffic conditions to maximize the resource utilization. In order to avoid excess delay in the resource allocation, the CAC and other resource management are processed on board the satellite.

CAC for variable bit rate (VBR) (real-time and non-real-time) and CBR services has been proposed in [6] using a probabilistic measure of the QoS guarantee by estimating the excess demand probability (which measures the probability of the resource unavailability of all admitted calls) in ATM-Satellite network. Unspecified bit rate (UBR) is also considered but without any CAC, i.e. with best effort policy. More description of the signaling and this CAC implementation is provided in [7]. A CAC scheme for voice and data services over low earth orbit satellite (LEOS) system has been proposed in [8]. The admission decision is based on the resource availability with a higher priority to the voice service.

3.0 CAC in Wireless Multihop/Ad-hoc Networks

Multi-hop/ad-hoc wireless networks have fundamental distinctions compared with classical wireless networks. Therefore, introducing novel CAC that takes into consideration the new characteristics is essential for providing acceptable QoS in multihop/ad-hoc wireless networks. These CAC schemes have to consider the lack of infrastructure (for ad-hoc networks), network connectivity, new interference model, traffic routing, decentralized implementation and power/energy limitation.

A framework for call admission in ad-hoc networks has been proposed in [9]. This framework tries to strike a balance between the network connectivity, which is enhanced by admitting more users and the signal quality in terms of the interference level that increases by admitting large number of users. The CAC concept classifies the incoming user as class 1 if (by admitting this user) the number of links will equal one of the critical values otherwise it is classified as class 2. The critical numbers of links, determined by the graph theory, are the ones that increase the connectivity of the existing nodes (users). For instance, when the number of links is equal to $((n/2).\log(n))$ or more, any node can reach other nodes using one or more hops, where n is the number of existing nodes. Class 1 users are admitted if the advantage of increasing the connectivity by admitting those users compensates the degradation in the signal quality due to the potential increase in the interference level while class 2 users are only admitted if the interference level (after admitting the incoming users) is acceptable. The admission decision is made by an appointed node, which is considered as a virtual cluster head.

In [10], a CAC scheme based on bandwidth availability in multihop network has been proposed. On demand routing and bandwidth reservation (at included nodes) are employed to explore the possibility of admitting the new (real-time) call. If no routes could be found such that all nodes in that route can be allocated the required resources in terms of the number of tome slots, the call is rejected. Time slot reallocation is not considered to alleviate the problem of time-slot matching between neighbor nodes.

A threshold-based CAC for wireless multi-hop voice/data network using circuit switching has been presented in [11]. Before admitting a call, the number of calls per circuit (connecting a source/destination pair) is checked whether it is less than a threshold value. Also, the sum of the number in each pair of circuits intersecting at any node is checked to ensure that it is less than another threshold value. The threshold values are chosen to minimize the blocking probability using the ordinal optimization techniques.

The CAC scheme proposed in [12] uses adaptive prioritization schemes and resource availability for burst admission in ad-hoc wireless networks. For instance, services with lower delay tolerance are admitted first, then services with higher delay tolerance, which can be queued until resources become available. Arriving bursts send their requests to the cluster head that manage the resource availability and prioritization scheme. Results show that the proposed scheme outperforms classical non-prioritized burst admission schemes such as first-come-first-serve (FCFS) in terms of P_b.

In [13], a measurement-based CAC has been proposed. When a new call arrives, it first transmits probing packets. The delay incurred by the probing packets is used to determine the service curve, which quantifies the network loading status. The measured service curve is compared by a pre-specified service curve corresponding to the QoS requirements. The CAC scheme accepts the call if the measured service curve is above the universal service curve; otherwise the call is rejected.

Three CAC schemes for ad-hoc wireless local are networks (LANs) have been proposed in [14]. The master device (node) decides whether to admit the arriving call based on the total amount of resources and estimated aggregate link utilization by all existing users. The three schemes differ mainly in the estimation technique of the aggregate link utilization taking into account the burst nature of the traffic. The first scheme uses the sum of the peak rates of different users as an estimate of the aggregate link utilization. Although this scheme is very simple and can guarantee a low packet loss rate, the conservative estimate leads to a very high blocking rate (up to 50%). The second and third schemes use the effective bandwidth technique to estimate the link utilization. The probability of the aggregate link utilization is approximated using the Hoeffding bound [15] and Gaussian distribution in the second and third schemes respectively. Results show that when a low packet loss rate is required, the Hoeffding bound based scheme can maximize the aggregate utilization better than the Gaussian distribution based scheme. On the other hand, the Gaussian distribution based scheme is more effective in reducing the locking rate if a high packet loss ratio can be tolerated. A similar strategy is used in [16] for mobile ad-hoc networks (MANETs). The aggregate link utilization is estimated based on the number of nodes sharing the link and a utilization factor determined empirically (by simulation). However, it should be noticed that the utilization factor value is sensitive to many systems parameters and it has to be determined for each particular network configuration.

4.0 CAC in HAAP Station

High altitude aeronautical platform (HAAP) has been proposed to combine the advantages of terrestrial and satellite systems while avoiding most of the disadvantages of both systems [17]. As shown in Fig. 2, HAAP provides the advantage of covering large areas with minimum infrastructure and having centralized system control and global information. Nevertheless, the transmitted power in the downlink is significantly limited compared with terrestrial wireless networks.

Two power-constrained SIR-based CAC schemes have been proposed for downlink admission in [18]. The first algorithm restricts the maximum transmitted power per base station (BS) while the second scheme restricts the maximum total transmitted power. It is clear that the second algorithm is more efficient and causes less blocking due to the statistical multiplexing. In both algorithms the call is only admitted if the SIR constraints of all users in all cells can be satisfied without violating the maximum power constraint.

Due to the availability of global information at the HAAP station, it is feasible to calculate the SIR for all users in all cells. The admission for uplink in HAAP is proposed in [19]. The CAC scheme admits the incoming call if the SIR constraints at all BS are met. The SIR is checked by calculating the total received power at all BSs.

5.0 CAC in hierarchical cell structure

Hierarchical network structure consists of two or more tiers (macro-cells, micro-cells, pico-cells, etc.) as shown in Fig. 3. In this case, CAC schemes do not only decide whether to admit the incoming call but also direct the incoming calls to the proper layer. In [20], two algorithms have been proposed. The first one, called Uniform Call Admission (UCA), directs all calls (voice or data, new or handoff) to micro-cells first. If no channels are available in the micro-cells, the incoming call is then redirected to the corresponding macro-cells. Unlike UCA, the second algorithm, called Non-uniform Call Admission (NCA), directs data calls to macro-cells first and if all channels in the macro-cells are occu-

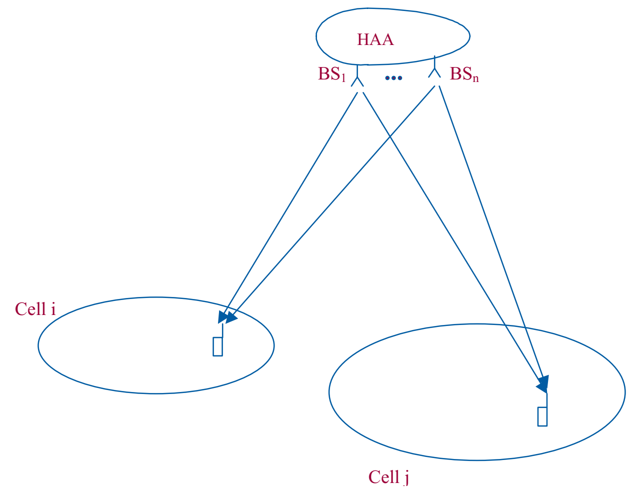

Figure 2: High altitude aeronautical platform (HAAP) system

pied the data call is then redirected to micro-cells. Voice calls are handled as in UCA. This is based on the assumption that data calls residence time is much larger than the voice calls residence time. Results show that UCA algorithm outperforms NCA algorithm in terms of the blocking and dropping probabilities.

A CAC scheme has been proposed in [21] to maximize the system capacity while maintaining an upper bound of the outage probability and blocking probability in hierarchical cell structure. The spectrum is reused in different layers (micro-cells and macro-cells) using a special pattern to minimize inter-layer interference as explained in [22]. Modified linear programming techniques used to solve the optimization problem and find the maximum loading factor in cell layer.

CAC in code division multiple access (CDMA) hierarchical cell structure is considered in [23]. While the admission of the arriving call in micro-cells is based on the interference level in the home cell, the admission of incoming calls in macro-cells is based on interference level in the home cell as well as the adjacent cells. This is because the propagation model in the macro-cell leads to more interference than the Manhattan-model assumed in the micro-cells.

6.0 Conclusions

CAC in special wireless networks has been discussed in this article through a survey of the literature. Different aspects of CAC schemes have been addressed in multihop/ad-hoc wireless networks, satellite networks, high altitude aeronautical platform stations, and hierarchical cellular wireless networks. It has been shown that CAC schemes play a central role in the QoS provisioning.

In future wireless networks, RRM is becoming more challenging because of the anticipated heterogeneous environment taking into account the various access technologies, the broad range of QoS requirements, the amount of available information, and stringent QoS requirements comparable to those of broadband wireline networks. It is anticipated that different networks and access technologies will coexist in the future wireless networks. Henceforth, fourth generation (4G) wireless networks will encompass third generation (3G) wireless systems (including hierarchical cellular structures) , wireless local area networks (WLAN) such as IEEE 802.11 family and High Performance Radio Local Area Network (HIPERLAN), satellite and high altitude platform networks, ad-hoc wireless networks and broadband wireless access metropolitan area network (MAN) such as IEEE 802.16. Therefore, novel RRM in general and CAC in particular are needed to deal with the anticipated new composite radio wireless environment.

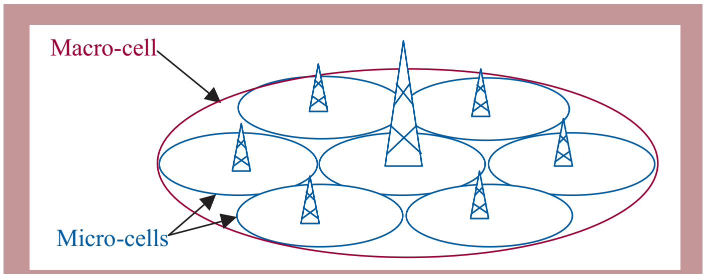

Figure 3: Hierarchical Cellular Structure

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About the author

Mohamed Ahmed received B.Sc. and M.Sc. in electronics and communications engineering from Ain Shams University, Cairo, Egypt in 1990 and 1994, respectively. He received a Ph.D. in 2001 from Carleton University, Ottawa. From Mar. 2001 to Mar. 2003 he worked as a senior research associate in the department of systems and computer engineering at Carleton University. In April 2003 he joined the faculty of engineering and applied science, Memorial University of Newfoundland, as an assistant professor. He has served as a technical program committee member of various conferences and as a guest editor for the Wiley Journal on Wireless Communications & Mobile Computing. He won the Ontario Graduate Scholarship for Science and Technology in 1997, the Ontario Graduate Scholarship in 1998, 1999 and 2000, and the Communication and Information Technology Ontario (CITO) graduate award in 2000. His research interests include wireless access techniques, resource management in wireless networks, smart antennas and MIMO systems, multi-hop and ad-hoc wireless networks, 3G and 4G wireless systems, and fixed wireless networks. He can be reached at mhahmed@engr.mun.ca.

Letters to the Editor

Subject: Erratum

Dear Editor,

An erratum appeared in the article "On the Cooperative Control of Multiple Unmanned Aerial Vehicles" (pages 15-19) which was published in the IEEE Canadian Review 2004 (Edition CR46). The article should have made due reference to the following scientific proposal on UAV cooperative control that had been officially submitted, prior to publication of IEEE CR 2004, by the authors of the article along with colleague scientists from Defence R&D Canada - Ottawa and the Canadian Forces Experimentation Center of the Department of National Defence of Canada, and from the University of Montreal Center for Research on Transportation. This additional reference is:

M. Lauzon, P. Hubbard, C.A. Rabbath, E. Gagnon, B. Kim, P. Farrell and T. Crainic, "Trusted Uninhabited Vehicle Autonomy Through Time-Constrained Decentralized Model Predictive Control", Project Proposal, Technology Investment Fund Program, Defence R&D Canada, May 2003.

We would appreciate if this erratum could be published in an upcoming issue of the IEEE Canadian Review.

Dr. C.A. Rabbath, Dr. E. Gagnon and Mr. M. Lauzon

Quebec

Subject: IEEE Canadian Review #49 question

Dear Editor,

I have a question regarding a statement in the article "A History of Electric Power Development in Manitoba" (Winter 2005). The article includes the sentence "This was six years before Edison invented the incandescent lamp."

Yet, the following text appeared in the Ottawa Citizen not too long ago:

"Thomas Edison is often credited with the invention of the light bulb, but Torontonians Henry Woodward and Matthew Evans beat him to the switch when they patented a bulb in 1875. When the two couldn't raise enough cash to make their product commercially viable, Edison, who like many others at the time had been working on a similar idea, bought the rights to their patent. Using different techniques and improvements, Edison's bulb was ready for patenting in 1879 and has remained in the spotlight ever since."

Now and then I read conflicting reports on who invented the light bulb. Can you point me to a good article or paper on the light bulb invention story. I would like to understand why there is an apparent lack of agreement on who invented the light bulb.

Dave Hall

Ottawa, ON

Subject: IEEE Canadian Foundation: 2005 IEEE Canada Women In Engineering Prize

Dear Editor,

I am pleased to advise that after careful consideration by the full Board of Directors, the IEEE Canadian Foundation has agreed to award the IEEE Canada Women in Engineering Prize for 2005 to **Jennifer Jessop** of the Winnipeg Section, as nominated by **Jeff Blais**.

This Prize is awarded to a female IEEE Canada member who received her first professional degree within the last ten years and who is active in IEEE activities - value $500. This year, 2005, is the first that the Prize has been awarded.

A framed certificate being prepared by the ICF will be presented to the Prize winner by the Section Chair at a suitable IEEE Section or National Meeting.

Our Treasurer, Luc Matteau, will arrange to forward the funds.

Congratulations!

David Whyte

ICF Grants Committee Chair