CHANNEL CONGESTION CONTROL IN MOBILE CELLULAR NETWORKS: A SURVEY

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ABSTRACT

This article produces a review of call admission control and resources allocation schemes for cellular networks users and the findings in this area. Our goal is to provide survey of reviewed researches of a broad classification and detailed discussion of the existing call admission control schemes and allocation of bandwidths allocations that reduce the congestion issues in the network environment. The discussion of several admission control schemes and their comparison in terms of performance metrics: complexity, flexibility, stability, adaptively, overhead were all looked at holistically and analysed as a motivating factor for this work, and the future trends in Teletraffic engineering. It is therefore discovered that some schemes are better than the others in curtailing the resource utilization crises in cellular network.

Keywords- Base Station, Call admission, Call dropping, Congestion, Cell, Handoff, QoS, Resource allocation, Traffic.

1. INTRODUCTION

Present and more importantly the future generations of GSM mobile cellular networks are to ensure support for a variety of network applications with varied demands. This diverse application demands could result to assured congestion from call droppings and call blockings. Congestion in Telecommunication engineering means the unavailability of network resources (bandwidth: frequency, time and code slots or power) when the subscribers requested the resources for use to initiate call in GSM network [1]. A channel can be a frequency, a time slot or a code slot or even power that a limited number of users are competing to use. The terminal residing in a cell can communicate via a radio link or a bandwidth with the base station resided in the said cell, which communicates with the Mobile Switching Center (MSC), and which also in turn connected to the Public Switched Telephone Networks in a well-structured network layout. A resource congested channel occurs when there is unavailability of the network resources to the subscriber at the time of request. [2] Reserving of network resources trunk was studied in [3,4] where multiple-rate requests are blocked once bandwidth used by certain flow is above specific reservation size. The method of call admission control algorithms for mobile cellular networks is peculiarly tasking under the scarce and highly competitive channel resources and their allocation to numerous users.

The Congestion is broadly divided into physical and logical channel congestion. Physical Channel is the one over which the information is carried and Logical Channels consists of the information carried over the physical channel.

The Logical channel is subdivided into Control channel and Traffic channel. The Control channel is use to exchange information having to do with setting up and maintaining calls while the Traffic channel carries voice or data connection among the users. The goal of the admission control algorithm is to admit as many mobile users as possible with the requested QoS and achieve a very high utilization of the resources. However, when call from a new mobile user is admitted, the system should that it meets its prior commitments by keeping agreeing with the QoS to previously admitted users [9]. The technique of the shadow cluster concept is a remedy to the problems of resource reservation and call admission in a cellular network. It is among the first scheme that utilizes real-time information about the dynamics, traffic patterns, and bandwidth utilization of respective mobile terminals in a network. The shadow cluster scheme is *dynamic and proactive* which is the amount of resources to be kept as determined "on-the-fly," and the control functions on call admissions are aimed at preventing the congestion conditions [9].

The admission of the new of call to access network resources is determine by the traffic situation which might result to blocking or allowing the user. The flow is illustrated in fig.1.

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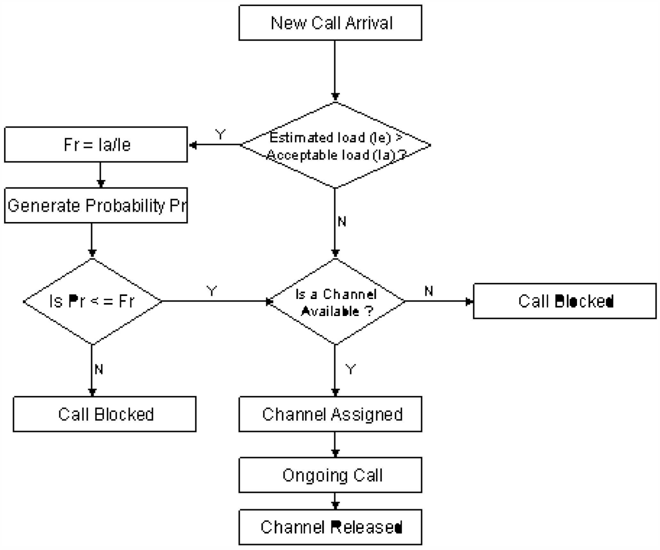

Fig.1. Flow chart for CAC algorithm[]

In [1] abrupt termination of calls already in progress happens if resources are not in idle state when a user experiences a handover. Abrupt termination is known to be more serious than blocking of new call attempts negotiating for resources, so it is very important to avoid or minimize forced termination if only and only if it does not negatively affect other classes of traffic users. To reduce the extent of blocking, though it might be costly, an increase in network capacity can be obtained by increasing the number of channels in a cell, decreasing the cell size, and also develop efficient power control scheme.

In resolving the hand-off drops problem, the adaptive QoS schemes have been proposed in which a connection's QoS can be downgraded when there is a little bandwidth available in the present new cell [5]. QoS adaptation can be achievable without the bandwidth reservation, and when both are used together, bandwidth reservation is used on the basis of the minimum QoS of each connection with adaptive QoS scheme. Reserved bandwidth can be used only for hand-offs from neighboring cells, but not by newly-requested connections in the cell. A connection is known by its demanded bandwidth, and a newly-requested connection in a cell requires a very simple admission test:

$$\sum_i bi + bnew \leq C - Br \quad (1)$$

where C is the link capacity, Br, is the target reservation bandwidth, which is the required bandwidth to be reserved for hand-over, b*i*, is the bandwidth being used by the current connection *i*, and b_{new} is the bandwidth required by the newly-requested connection outlined by [10]. Upon arrival of a new connection request, Br, is updated predicatively and adaptively - before conducting the admission test (1) on the request - base on the traffic status in neighboring cells. But B, is a target, not the real reserved bandwidth, since a cell may not be able to reserve the requested bandwidth, thus,

$$\sum_i bi + bnew \leq C - B > C \ . \quad (2)$$

For this, a Base Station can control the admission of only newly-requested connections, not those connections handed off from nearest cells. This therefore shows that the bandwidth reservation is specifically based on information from adjacent cells such as the number of existing connections and their bandwidth-resourced requirements. Thus, it is very vital to maintain inter-BS communications in the cellular network [6]. The analysed model for handoff calls was proposed by [7] that the distribution of the number of the handoff for a random call is to obtain the probability that a random call goes through at least ***x*** handoffs for any integer value of ***x***. This probability can be derived by computing the four conditional probabilities corresponding to the four possible directions of motion for a mobile. Therefore, Conditional probabilities are used to generate the probability distribution of the time t to then xth cell boundary crossing. Once we have this distribution, we obtain the probability at least n handoffs by noticing that for a call with service time equal *to t* a time to the nth cell boundary crossing smaller or equal to *t* insures at least ***x*** handoffs before the call ends. Therefore, the probability that a call goes through at least x handoffs is given by

$$P{\geq}xH = \int_0^{\infty} p[Tx \leq t] S(t)dt \quad (3)$$

Where P[Tx≤t] is the probability that the xth boundary crossing takes place before time *t,* and *s(t)* is the service time density function.

2. BASIC CONCEPTS

***Blocking Probability**:* This blocking probability of a new –β type call from a –α type platform is the average fraction of new –β type call attempts from –α type platforms which are denied access to a channel. Blocking of a new –α type call attempting to gain a channel from a –β type platform occurs if there are no channels available to serve the call or if the system's channel quotas are already full. We define the following disjoint sets [8]

$$PB(\beta, \alpha) = \textstyle\sum_{S \in Bo} P(s) + \sum_{s \in BJ} p(S) \quad (4)$$

$$B_o = (s: c - ch \leq j(s) \leq C \quad (5)$$

$$(s: c - ch \leq j(s) \leq C, j(s,\beta,\alpha) = J(\beta,\alpha) \quad (6)$$

Hand-Off Failure Probability

The hand-off failure probability for –β type calls being served on –α type platforms is defined as the average fraction of hand-off attempts that are denied a channel. A hand-off attempt of a –β type call on board a –α type platform will fail if no channels are available in the targeted cell (recall that hand-off attempts have access to all channels) or if the cell's channel quota is already full. We have the following disjoint sets:

$$H_o = \{S:j(S)=C\} \quad (7)$$

$$H_j = \{S:j(S)<C, j(S,\beta,\alpha)=J(\beta,\alpha) \quad (8)$$

The hand-off failure probability for –β type calls served on -α type platforms is

$$P_H(\beta,\alpha) == \textstyle\sum_{S \in Ho} P(S) + \sum_{S \in HJ} P(S) \quad (9)$$

Carried Traffic

The carried traffic per cell for each call and platform type is the average number of channels occupied by the calls from the given platform type. The carried traffic for –β type calls on board –α type platforms is

$$A_C(\beta,\alpha) = \pi \textstyle\sum_{s=0}^{Smax} j(s,\beta,\alpha). P(s) \quad (10)$$

$$A_C = r^2 \textstyle\sum_{\beta=1}^{W} \sum_{\alpha=1}^{G} Ac(\beta,\alpha) \quad (11)$$

when there is no available resources for the call to handover to a new a cell, the granted call will be forced to terminate which is the Call Drop and its probability is called Call Dropping Probability (P_d). Handover calls are given preferential treatment than a new call, as it can often lead users' QoS degradation and accepting new will increase call blocking rate. Generally, dropping a call in progress is considered to have a more negative deformative effect from the user's perspective than blocking a newly requested call.
The most schemes to prioritize handover calls against new calls is by reserving a portion of available bandwidth in each cell to be used specifically for handover call.
If H is the number of handoffs throughout the duration of a call then

$$p_d = 1-(1-p_f)^H \tag{12}$$

Where H is a random variable. Therefore, in average

$$p_d = 1-\sum_{h=0}^{\infty}(1-p_f)^h \Pr(H=h) \tag{13}$$

The Call Completion Probability (P_c) has a relationship between Call Blocking Probability (P_b) and Call Drop Probability (P_d)

$$P_c = (1-P_b)(1-P_d) \tag{14}$$

3.0 SCHEMES FOR CALL CONGESTION CONTROL

The fig.2 shows the various methods to resolve GSM Teletraffic problems in GSM network.

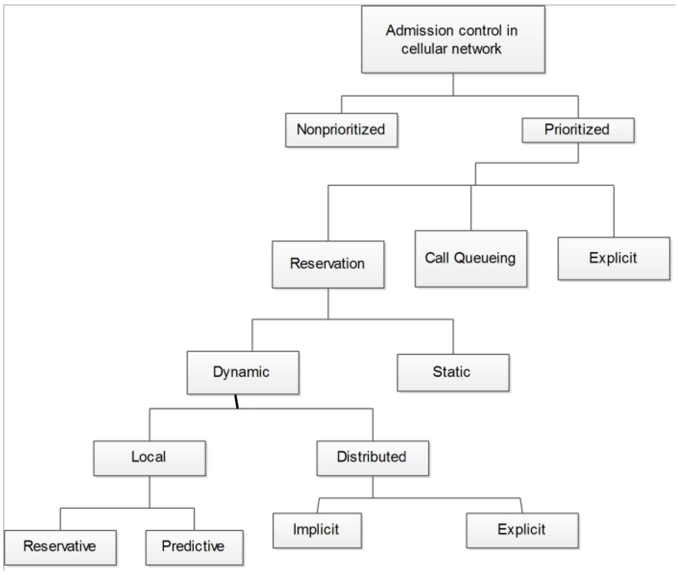

Fig.2 Random Variable Call Admission Control Schemes [8]

3.1 Prioritization Schemes

In this part, the different types of handoff prioritization schemes are studied with emphasis on reservation model. Those other schemes are as: reservation, call queuing, channel borrowing techniques. Links with higher costs are allocated to higher priorities in case of channel assignment over the links with lower cost and Scheduling the links becomes harder because the links with higher costs suffer from the higher levels of congestion.

3.2 Reservation Schemes

The idea of guard channels was conceived in the 80s as a call admission control technique to give priority to handoff calls over new call requests. Thus, a set of channels called guard channels are permanently kept for handoff calls according to [14] which showed that this scheme scale down handoff dropping probability (p_d) greatly compared to the nonprioritized case. It was found that handoff dropping probability decreases by a significantly larger order of size compared to the increase of pb when more priority is given to handoff calls by increasing the number of handoff channels. Considering a mobile network with C channels in a given cell, the following holds . The guard channel scheme (G_c) reserves a subset of these channels, say C − t, for handoff calls. Whenever the channel occupancy passes a certain predefined threshold t, G_c rejects new calls until the channel occupancy goes below the threshold. Taking the arrival process of new and handoff calls as a Poisson with rate λ and ν respectively. The call holding time and cell residency for both types of call is exponentially distributed with mean 1/μ and 1/ η, respectively. Let ρ = (λ + ν)/ (μ + η) denotes the traffic intensity. Further assume that the cellular network is no dual in nature, thus a single cell in isolation is a representative for the network.

Define the state of a cell by the number of occupied channels in the cell. Therefore, the cell channel occupancy can be modeled by a continuous time Markov chain with C states. The state transition diagram of a cell with C channels and C−t guard channels is shown in Fig. 3.

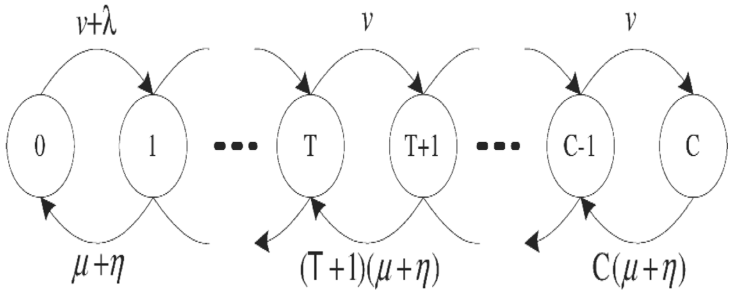

Fig. 3. State transition diagram of the guard channel

Given this, it is straight forward to derive the steady-state probability, P_n that n channels are busy and where the following relationships exist.

$$P_n = \begin{cases} \left(\frac{P^n}{n!}\right) P_o, 0 \le n \le t \\ P^t\left(\frac{V^{n-t}}{n!}\right)P_{o,} t \le n \le C \end{cases} \tag{15}$$

$$P_0 = \left[\sum_{n=o}^{t} \frac{\rho^n}{n!} + \rho^t \sum_{n=t+1}^{C} \frac{V^{n-t}}{n!}\right]^{-1} \quad (16)$$

And then $P_0 = \sum_{n=t\_+1}^{C} P_n$ and pf $=P_c$.

3.3 Dynamic Reservation Schemes

Two approaches of dynamic reservation schemes have been mentioned in the literature namely are local and distributed dynamic reservation schemes. In local reservation schemes, each cell calculate the state of the network using local information only unlike in distributed schemes where each cell gathers network state information from its neighboring cells. Local admission control schemes subdivided into reactive and predictive schemes.

By reactive approaches the admission policies that adjust their decision parameters, threshold and reservation level due to call arrival, completion or rejection is incumbent here. Predictive approaches are those policies that predict future events and regulate their parameters in advance to prevent undesirable QoS debasements [13].

3.3.1 Distributed Schemes

Here, a group of cells which are geographically or logically close together form a cluster [15]. The admission decision for a connection request is made in agreement with other cells of the cluster.

Distributed CACs can be subdivided into implicit or explicit.

3.3.2 Implicit Approach: All the necessary information is obtained from the neighboring cells and locally processed. The network controller is responsible for keeping track of the users and resources, and not minding the locally gathered information and the final decision is made locally.

3.3.3 Explicit Approach: This approach gathers information from the neighboring cells and involving them in the decision making. The shadow cluster concept is shown in [13]. In this scheme a cluster of cells, the shadow cluster, is associated with each mobile devices in a cell. Performance comparison of different CAC is as stated in Table 1.

Table1. Comparison between Distributed and Local Dynamic Call Admission Controls (CAC)

CAC	**scheme**	**overhead**	**efficiency**	**adaptivity**	**complexity**
Distributed	Explicit	High	High	High	Very High
	Implicit	Very High	High	High	High
local	Reactive	Low	Low	Moderate	Low
	Predictive	low	Moderate	Moderate	Moderate

4.0 CONNCLUSION

In this paper, a survey of the major call admission control approaches and related issues for designing efficient schemes have been discussed and analysed. For each category, the explanations of the main idea and approaches have been presented. Performance analysis of CAC has also been presented.

REFERENCES

[1] K. Mitchell and K. Sohraby, "*An Analysis of the Effects of Mobility onBandwidth Allocation Strategies inMulti-Class Cellular Wireless Networks*,"IEEE INFOCOM 2001.

[2] L.Brewka, V.B. Inversen and G. Kardaras, "*Integrated service resource reservation using queueing networks theory*", The Institution of Engineering and Technology 2014, Vol. 3, Iss. 1, pp. 16–21.

[3] I.D.Moscholios,J.Vardakas,M.Logothetis,A.Boucouvalas, 'The Erlang multirate loss model with Batched Poisson arrival processes under the bandwidth reservation policy', special issue on "*Heterogeneous networks: traffic engineering and performance evaluation*", Comput. Commun., 2010, 33, (Supplement 1), pp. S167–S179.

[4] Stasiak, M., Głąbowski, M, "*A simple approximation of the link model with reservation by a one-dimensional Markov chain*", Perform. Eval., 2000, 41, (2–3), pp. 195–208)

[5] K. Lee, "*supporting mobile multimedia in integrated service networks*," ACM Wireless Networks, vol.2, pp. 205-217,1996

[6] Sunghyun Choi and Kang G. Shin, "*Predictive and Adaptive Bandwidth Reservation for Handoffs in QoS Sensitive Cellular Networks*."

[7] Roch A. Gue'rin, Member, IEEE, "*Channel Occupancy Time Distribution in a Cellular Radio System*," IEEE Transactions Vehicular Technology, vol.VT-35, No.3, August 1987.

[8] P.V. Orlik and S.S. Rappaport, Fellow, IEEE, "*A model for Teletraffic performance and channel Holding Time characterization in wireless cellular communication with General session and Dwell Time Distribution*,"IEEE Journal on selected Areas in communications, vol.16, No.5, June, 1998

[9] A.K. Talukdar et al, "*Integrated Services Packets Network with mobile Hosts: Architecture and Performance*," Wireless Networks 5(1999) 111-124

[10] D.A. Levin et al, "*A Resource Estimation and Call Admission Algorithm for wireless multimedia Networks using the Shadow Cluster concept*," IEEE/ACM Transactions on Networking, vol.5, No.1, February 1997

[11] Majid Ghaderi and Raouf Boutaba, "*Call Admission Control in Mobile Cellular Networks: A Comprehensive Survey*".

[12] Y. Fang et al, "*Channel Occupancy Times and Handoff rate for Mobile Computing and PCS Networks*," IEEE Transaction on Computers, vol.47, No.6, pp.679-692, June 1998.

[13] J.R. Moorman and J.W. Lockwood, "*Wireless Call Admission Control using threshold access Sharing*," in proc. IEEE GLOBECOM'01, vol.6,San Antonio, USA, Nov. 2001,pp. 3698-3703.

[14] D. Hong and S. S. Rappaport, "*Traffic model and performance analysis for cellular mobile radio telephone systems with prioritized and nonprioritized handoff procedures*," *IEEE Transactions on VehicularTechnology*, vol. 35, no. 3, pp. 77–92,Aug. 1986, see also: CEAS Tech. Rep. No. 773, College of Engineering and Applied Sciences, State University of New York, June 1999

[15] M. Naghshineh and M. Schwartz, "*Distributed call admission control in mobile/wireless networks*," *IEEE Journal on Selected Areas in Communications*, vol. 14, no. 4, pp. 711–717, May 1996.