

Performance Evaluation of Multi Agent Based Call Admission in Cellular Networks

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Abstract— A Multi-agent System can be defined as a set of agents that interact with each other and with the environment to solve a particular problem in a coordinated (behaviorally coherent) manner. Our paper models Call Admission Control in Cellular networks as Multi Agent resource provisioning problem to provide Service Level Agreement (SLA) in wireless cellular network.

For which we modify SHUFFLE model to introduce Network Provider Cell Agent which implements three Call admission strategies namely Static CutOff Priority , Dynamic Call Admission and Mobility Based Channel Reservations strategies for single traffic class using Multi Agent Environment using Java Agent Development Framework.

The Paper evaluates the performance of call level parameters of CAC strategies along with performance parameters in Non Agent and Multi Agent System.

Index Terms— Multi Agent, Call Admission Control, JADE

I. INTRODUCTION

Multi Agent System extends the intelligent agent paradigm to improve upon the conceptual model of designing problems through agent interaction. This interaction could be of the form of collaboration, cooperation or even negotiation through Agent Communication Languages [11].

Service Level Agreement (SLA) is a pact between service providers (SP) and network providers (NP) or between service providers and customers specifying service guarantee in terms of service parameters, acceptable / unacceptable service levels, and action to be taken in special cases and penalties incurred by service provider in case the guarantee is not met. Call admission control (CAC) [10, 7, 6] is a fundamental mechanism used for quality of service (QoS) provisioning in a network by limiting the number of call connections into the networks in order guarantee Connection level QoS parameters such as new call blocking probability and handoff blocking probability, packet level QoS parameters such as delay, jitter, packet loss for various classes of traffic and mobility QoS parameters such as velocity, distance and direction of the movement of mobile terminal.

Although various call admission control schemes [3 ,4 6] have been researched thoroughly. The most direct previous work is that of IST Project SHUFFLE [2]. It presents agent based layered architecture for Network management. It divides agents according to their responsibility assigned in Negotiation Plane and

Resource Plane to meet the SLA. The work offers hypothesis that agents can be used for SLA control without offering implementation or performance analysis.

Our work is motivated by this SHUFFLE project, and intends in refining the model/architecture by introducing Network Provider Cell Agent (NPCA) as shown in fig. 1. By doing so two Multi agent System based Service Architectures: Centralized Network Provider Resource Agent (NPRA-based) and Distributed (NPCA-based) are proposed in our paper [8].

In this paper we present the performance of the CAC schemes implemented by these architectures and the analysis and evaluation of the same.

Section 2 details of the three CAC schemes: Static Cut Off Priority[5], Dynamic Cut Off Priority using D-CAC[7,10] and Mobility Based Channel Reservation based CAC[9]. Section 3 presents the MAS based model in JADE along with the FIPA performatives used for interaction amongst agents. Section 4 presents the simulations and results presenting connection level parameters along with comparative time of simulation required and message overhead involved in using Non agent and Multi agent environment along with analyzing these results.

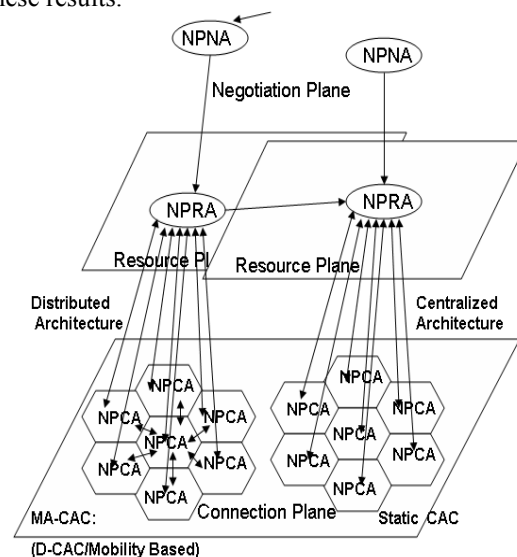


Figure 1. Extended Shuffle Model

II. CALL ADMISSION CONTROL

The two architectures can use following schemes for call admission.

A. Static Cutoff priority (S-CAC)

The Static Cutoff priority scheme [5] admits the calls in the cell if number of on-going calls in a cell is less than the threshold when new call arrives else the new call will be blocked. The handoff call is rejected only when all channels are used up.

If, λ and λ_h is the arrival rate of new calls and handoff call respectively and $1/\mu$ and $1/\mu_h$ are average channel holding time for new calls and handoff calls, also if m is the chosen cutoff threshold for j busy channels then the following stationary distribution for the approximate model is obtained with new call blocking probability and handoff call blocking probability as:

$$P_{nb}^a = \frac{\sum_{j=m}^c \frac{(\rho + \rho_h)^m \rho_h^{j-m}}{j!}}{\sum_{j=0}^m \frac{(\rho + \rho_h)^j}{j!} + \sum_{j=m+1}^c \frac{(\rho + \rho_h)^m \rho_h^{j-m}}{j!}} \quad (1)$$

$$P_{hb}^a = \frac{\frac{(\rho + \rho_h)^m \rho_h^{c-m}}{C!}}{\sum_{j=0}^m \frac{(\rho + \rho_h)^j}{j!} + \sum_{j=m+1}^c \frac{(\rho + \rho_h)^m \rho_h^{j-m}}{j!}} \quad (2)$$

Where $\rho = \lambda/\mu$ and $\rho_h = \lambda_h/\mu_h$

B. Dynamic Cutoff priority (D-CAC)

The Dynamic Cutoff Priority scheme [7, 10] requires the threshold of call admission of a new call to be calculated based on the ‘‘Ongoing Calls’’ rather than Fixed threshold.

We assume Manhattan, micro-cell network model. Also the mobile terminal can move in only 4 direction (top, right, bottom, left). The channel allocation scheme is fixed. Let a new call admission request be made in addition to the state of its adjacent cells T units of time after the call admission. Let N denote the number of calls which a cell can support. If n denotes ongoing calls in the current cell C , then t, r, b and l are the number of ongoing calls in neighboring cells (top, right, bottom, left) respectively. Let a new call admission request is made in addition to the state of its adjacent cells T units of time after the call admission. To calculate this threshold following conditions should be checked:

1) whether by admitting a new call at t_0+T , the current handoff probability of cell C_n , due to incoming handoff calls from C_t, C_r, C_b and C_l and also outgoing handoffs from C_n is less than the Threshold of call admission.

2) and whether the handoff probability of cell C_t ($C_r/C_b/C_l$) affected by handoffs from cell C_n , or the cell to the top, right, bottom and left of C_t to cell C_t and including handoffs from cell C_t , to any other cell, in addition to new calls admitted to cell C_t , during T , must be less than Threshold of call admission.

$$n_c = \frac{\left[\frac{a^2(1-p_s) + 2N - \text{SUM}p_m / 2 - \sqrt{a^2(1-p_s)^2 + 4N(1-p_s) + \text{SUM}p_m p_s - \text{SUM}p_m^2 / 4}}{2p_s} \right]}{2p_s} \quad (3)$$

$$n_r = \frac{\left[\frac{a^2(4-p_m) + 8(N-\lambda T - rp_s) - 2E(n)p_m - \sqrt{a^2(4-p_m)^2 + 64N + 16p_m(\lambda T + rp_s - N) - 64rp_s^2}}{2p_m} \right]}{2p_m} \quad (4)$$

$$n_c^{tol} = \min(n_c, n_t, n_r, n_b, n_l) \quad (5)$$

where $E(n)$ be the average calls per cell in the neighboring cells of C_t ($C_r/C_l/C_b$). Lets assume P_s is the probability that the call remains in the same cell. Let $P_m/4$ be the probability and a is tunable. This n_c^{tol} is substituted in equations (1) and (2) for D-CAC probabilities.

C. Mobility Based Channel Reservation (MBCR-CAC)

These schemes [9] propose that elapsed time of a call in a cell and the velocity class (high mobility/ low mobility user) of calls can characterize the extent influence a cell has on its neighboring cell. The more influence a call exerts on its neighboring cells ((top, right, bottom and left), the more likely a channel should be reserved in the neighboring cells to maintain the QoS requirement of this call. If cell dwell times for both classes of users have negative exponential distributions. Then

$$f_h(\tau) = \mu_h e^{-\mu_h \tau}, \quad f_l(\tau) = \mu_l e^{-\mu_l \tau}$$

where $1/\mu_h$ and $1/\mu_l$ are the average cell dwell times for high-speed users and low-speed users, respectively.

$$L_h(t, T) = 1 - e^{-\mu_h(T-t)}, \quad L_l(t, T) = 1 - e^{-\mu_l(T-t)}$$

Let $\alpha_{i,j}$ ($j \in Ni$) be the directional factor,

$$I_{i,j} = \sum_{k \in S} \alpha_{i,j} L(t_k, T) \quad (6)$$

$$R_{i,j} = BI_{i,j} \quad \text{where } B \text{ is tunable}$$

$$R_j = \sum_{i \in N_j} R_{i,j} \quad (7)$$

Hence at time T , cell j needs to reserve channels for possible handoff calls from its neighboring cells. This scheme requires that neighboring cells (top, right, bottom and left) exchange information with each other: cell i should report $R_{i,j}$ to all its neighbors. It is assumed that users are moving in a random movement pattern. Now from above equations

$$R_{i,j} = \frac{B}{4} \left[\sum_{k \in S_h} (1 - e^{-\mu_h(T-t_k)}) + \sum_{k \in S_l} (1 - e^{-\mu_l(T-t_k)}) \right] \quad (8)$$

The Integral mobility based CAC calculates the call admission probability as:

$$P_{new} = \begin{cases} 1 - B_{used} \leq C - R_j^1 - B_{new} \\ 0 - B_{used} > C - R_j^1 - B_{new} \end{cases} \quad (9)$$

Where P_{new} is the admission probability for new calls, B_{used} and B_{new} are the number of used channels and the number of channels required by the incoming new call, respectively. Note that R_j may not be an integer. In this scheme, R_j^1 is rounded off to the nearest integer R_j^1 , and use R_j^1 as the final target number of reserved channels.

In this scheme, because of rounding of reservation request some information carried by the fractional part

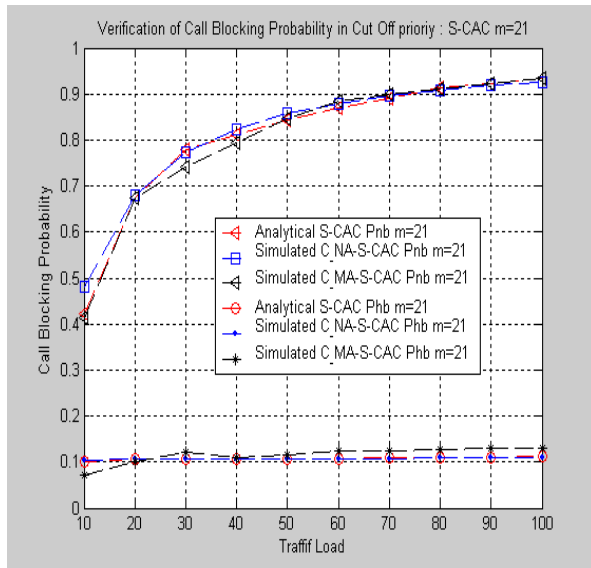


Figure 5. Verification of S-CAC

The system is simulated for single (voice) traffic class. The calls are admitted in NPRAs of 25 NPCAs. Manhattan model of 9 NPCA cluster having cell area of 4 square kilometer is considered. Each cell is given 30 channels. The new call arrival rate (λ) which forms a Poisson process is taken as 20. The traffic load is varied from 10 to 100 Erlang. Handoffs are performed automatically based on RSS value or parameterized handoff threshold. Emulation of forced call termination on insufficient signal strength is implemented. The fig. 5 verifies the blocking probabilities of Centralized S-CAC schemes which are plotted for Non Agent as well as Multi Agent Environment, for threshold $m=21$.

In Fig. 6 comparison of call level parameters of Centralized S-CAC and D-CAC are plotted. We see that the new call blocking probability (P_{nb}) of D-CAC is less in case of less load but is high as compared to S-CAC $m=25$ for higher traffic. It remains in between S-CAC P_{nb} $m=27$ to S-CAC P_{nb} $m=21$. The handoff call blocking probability (P_{hb}) is very less as compared to the that of S-CAC. This is because unlike in S-CAC the cutoff threshold changes dynamically in D-CAC and as the traffic load increases, more call are available in the neighboring cells so less calls are admitted in current cell threshold P_{nb} and thus implicitly increasing the channels for handoff calls thus reducing the handoff call dropping probability.

TABLE II
MESSAGE PASSING OVERHEAD (NO. OF MESSAGES)

Number of Calls	Multi Agent Based		
	C_MA-S-CAC	D_MA-S-CAC	D_MA-D-CAC
25000	503493	1509792	1258740
50000	1018441	3015494	2519904
75000	1525696	4528653	3778638
100000	2039653	6038237	5038136
1250000	2545996	7548497	6293734

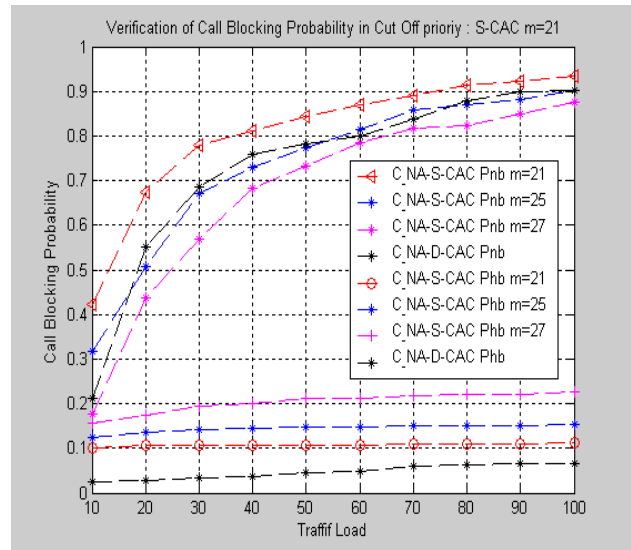


Figure 6. Comparing C_S-CAC and C_D-CAC call level parameters

In D-CAC the user velocity and thus the dwell time of a call is constant. Mobility based schemes reserve channels for handoff calls implicitly defining threshold for new calls. The probabilities vary depending on the real time traffic as the thresholds depend on influence parameters. The call level parameters of Multi Agent based and Non Agent based schemes for Distributed architectures D_D-CAC and D_MBCRs are compared in fig. 7 and fig. 8. We see that the new call blocking probability of D-CAC is higher as compared to in MBCR schemes. Whereas its handoff blocking probability is in between that of the two mobility based schemes. The new call blocking of both mobility based schemes are almost same where as there is significant reduction in case of Fractional scheme. This is because of the rounding effect as explained in earlier section. MBCR-CACs fair well as compared to D-CAC.

Although message overhead in table I is higher in Distributed architecture as compared to Centralized architecture but again it is less by about 20 % in D-CAC scheme as compared to S-CAC scheme for Distributed architecture.

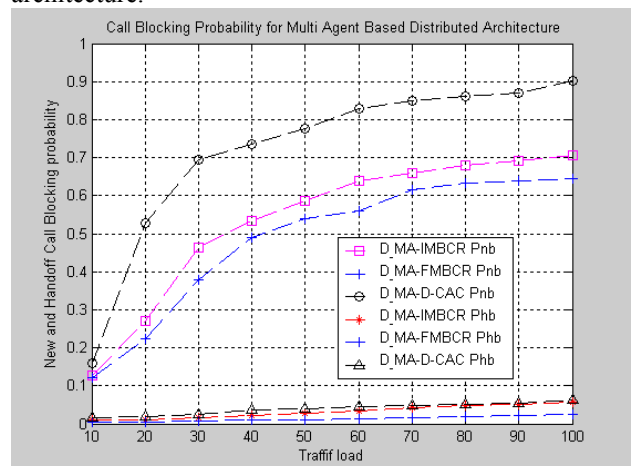


Figure 7. Comparing Multi Agent based D_D-CAC and D_MBCR Call level parameter

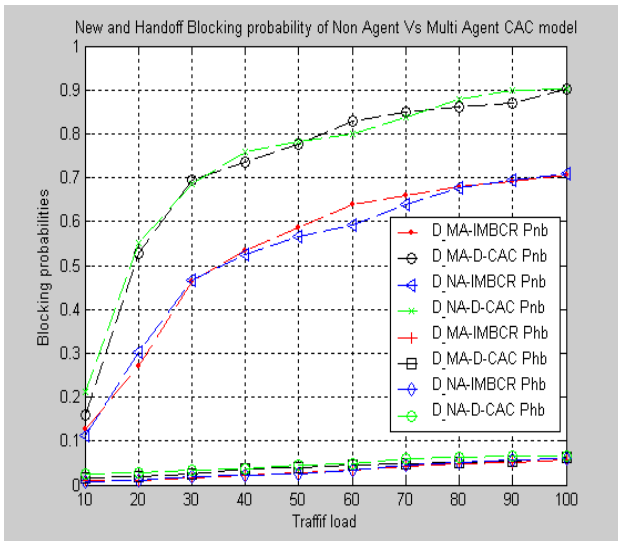


Figure 8. Comparing Call level Parameters of Multi Agent and Non Agent based schemes for Distributed architecture

TABLE III

SIMULATION TIME (S) FOR NON AGENT VS MULTI AGENT

No. of Calls	Centralised Dynamic scheme (D-CAC)		
	C_NA_D-CAC	C_MA-D-CAC	Appr. % reduction
25000	1694.58	1301.40	23
50000	3372.50	2584.57	23
75000	5120.25	3977.56	22
1,00,000	6815.72	5302.04	22
1,25,000	8740.68	6682.01	23

TABLE IV

SIMULATION TIME (S)FOR NON AGENT VS MULTI AGENT

No. of Calls	Distributed MBCR schemes		
	D_NA_IMBCR	D_MA_IMBCR	Appr. % reduction
25000	873.422	778.33	11
50000	1625.47	1455.38	11
75000	2947.5	2625.90	11
1,00,000	3736.21	3344	11
1,25,000	4614.02	3992.64	13

TABLE V

SIMULATION TIME(S) FOR COMPARISON OF MULTI AGENT BASED CENTRALISED VS DISTRIBUTED SLA ARCHITECTURE

No. of Calls	Dynamic schemes (D-CAC)		
	C_MA_D-CAC	D_MA_D-CAC	Appr. % reduction
25000	1301.40	983.57	24
50000	2584.57	1928.92	25
75000	3977.56	3075.95	23
1,00,000	5302.04	3992.45	25
1,25,000	6682.01	4986.95	25

TABLE VI

SIMULATION TIME (S) FOR NON AGENT VS MULTI AGENT BASED CENTRALISED VS DISTRIBUTED ARCHITECTURE

No. of Calls	Dynamic schemes (D-CAC)		
	C_NA_D-CAC	D_MA_D-CAC	Appr. % reduction
25000	1694.58	983.57	42
50000	3372.50	1928.92	43
75000	5120.25	3075.95	40
1,00,000	6815.72	3992.45	42
1,25,000	8740.68	4986.95	43

Tables III - IV give us an estimate of the reactivity of MA-Based CAC over non agent based CACs for Centralized as well as Distributed SLA architectures. We see that by using Agent based schemes there is a significant reduction in simulation time, approximately of 22-23% in case of Centralised D-CAC, 11-12% in case of Distributed MBCR-CACs also as shown in tables V and IV the Distributed architecture scheme (D-MA-D-CAC) using Multi Agent schemes is faster as compared to the Centralized Non Agent based (C_NA-D-CAC) as well as Centralized Multi Agent based schemes (C_MA-D-CAC).

The reason for difference between reduction in D-CAC and MBCR is due to the time requirement for probabilistic estimation of Cutoff threshold in case of D-CAC. The above schemes are simulated for single traffic class. The role of Multi Agent system needs to be exploited for congestion control for multi class traffic. Also various interaction models would bring better reactivity and balance of resources in the cellular system.

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