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PRIMARY ARTICLE

QoS Negotiation and Service Differentiation by CAC Scheme for 3G Wireless Cellular Networks

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ABSTRACT

In the 1G and 2G of wireless cellular systems, CAC has been developed for a single service environment. In the 3G and beyond wireless cellular systems, multimedia services such as video, data, and audio are to be offered with various QoS profiles. Hence, more sophisticated CAC schemes are needed to develop for dealing with these challenges. CAC is needed for admitting reasonable number of users in the sense that CAC can satisfy various QoS constraints for different services and also maximize the spectrum utilization for systems. CAC schemes play a very important role in the performance of 3G wireless cellular network systems as it directly controls the number of users in a cell and thus limit the interference in the system.CAC has been extensively studied in wireless cellular networks as an essential tool for congestion control and QoS provisioning. CAC in wireless cellular networks has been receiving a great deal of attention during the last two decades due to the growing popularity of wireless cellular network and the central role that CAC plays in QoS provisioning.
Quality of service (QoS) plays a major role in wireless cellular networks and it is one of the most important issues from both the users and operators point of view. All the parameters related to QoS are not same important for all users and requested applications. The satisfaction level of different users also does not depend on same QoS parameters. Our proposed CAC scheme gives preferential treatment to higher priority calls, such as hand-off calls of all class of service (data, voice and video), by reserving some bandwidth to reduce handoff failures. In addition, queuing is also used to enhance the hand-off success probability. The scheme uses the effective load as an admission criterion and applies different thresholds for new and hand-off calls. Finally, we consider three types of services: video, voice and data calls. We assure that our scheme reduces the drop hand-off calls by queuing mechanism and increases the system capacity; hence the Grade-of-Service (GoS) and the system performance can significantly improve.

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Call Admission Control (CAC), Interference Call Admission Control (ICAC) Quality-of-Service (QoS), Grade-of-Service (GoS), Universal Mobile Telecommunication System (UMTS).

I INTRODUCTION

The 3G wireless cellular mobile systems which are based on W-CDMA technology are expected to be interference limited. Soft capacity is one of the main characteristics of 3G (i.e. UMTS) and it requires new radio resource management strategies to serve diverse QoS requirements. [5]

Providing multimedia services with QoS guarantees in third generation wireless cellular networks poses great challenges due to bandwidth issue. The QoS provisioning means that the multimedia traffic should get predictable service from the available resources in the communication system. In most cases, QoS requirements are specified by the 3-tuple: (bandwidth, delay and reliability). [6]

In the 1G and 2G of wireless

cellular systems, CAC has been developed for a single service environment. In the 3G and beyond wireless cellular systems, multimedia services such as video, voice and data are to be offered with various QoS profiles. Hence, more sophisticated CAC schemes are developed to deal with these challenges. [7]

Allocating radio resources to users with minimum blocking of new calls and dropping of hand-offs has become a vital issue in cellular wireless networks system design. The task of the Admission Control (AC) is to decide whether or not to assign the radio resources the users request from the system. Admission control strategy will adopt proper admission criterion according to different QoS requirements and overall system performance. Currently, Effective and efficient radio resource management schemes need far more attention in 3G mobile cellular network systems and beyond. CAC schemes are critical to the success of future generations of wireless cellular networks. On one hand, CAC schemes provide the users with access to a wireless network for services. On the other hand, they are the decision making part of the network carriers with the objectives of providing services to users with guaranteed quality and at the same time, achieving as much as possible resource utilization. It is therefore conceivable that CAC policy is one of the critical design considerations in today's wireless cellular networks. Complex CAC is needed for admitting reasonable number of users in the sense that CAC can satisfy various QoS constraints for different services and also maximize the spectrum utilization for systems. CAC schemes play a very important role in the performance of 3G wireless cellular network systems as it directly controls the number of users in a cell and thus limit the interference in the system.

Call admission control (CAC) techniques must be introduced to guarantee that ail traffic types meet their quality of service (QoS) requirements. These are techniques that control the acceptance of different types of calls into the system. The necessary quality of service (QoS) is guaranteed in term of both call dropping and call blocking probabilities. A call admission control (CAC) strategy may block additional calls even if there are enough resources for the service in order to improve the systems fairness. Call admission control (CAC) is based on the knowledge of the statistical characteristics of ongoing and arriving calls. The decision to accept an additional call involves the calculation or estimation of the consequences of the call acceptance on blocking and delay of itself and other incoming calls.

The rest of the paper is organized as follows. In section II description about the estimation of system capacity and load is presented. Section III, provides a keynote of CAC scheme in today's wireless cellular networks along with our proposed work is presented. Section IV presents the obtained results through simulation, as well as the discussion about the results. Finally, we concluded the paper in section V.

II ESTIMATION OF SYSTEM CAPACITY AND LOAD

In most of the CAC scheme the acceptable load is calculated based on simulation results and this value is used for comparison purpose. The estimated load is also calculated and it is checked with the acceptable load. If the estimated load is lesser than or equal to the acceptable load, then attempts are made to allocate channels for all the incoming calls. If the estimated load is greater than the acceptable load then only a fraction of the incoming calls will be allocated channels and the remaining fraction of the calls will be discarded even if there are available channels. This is called pre-blocking of channels and this scheme improves the SCCR of the profiled users. [9]

This estimation provides the key criterion in designing the admission control. To design perfect admission control scheme, estimation of total interference playing an important role in the decision process of acceptance or rejection of new calls.

Bit-energy-to-noise-density ratio Eb/No corresponds to the signal quality, since it determines the BER. Let ρ be the target Eb/No required to achieve a particular BER, The resulting BER can then be approximated using:

$$Q[\sqrt{2E_b / N_o}] \approx \mathbf{e}(E_b / N_o) / 2\sqrt{\pi E_b / N_o} \qquad (1)$$

Let,

(W/Ri)i = Gi: is the spreading factor or the

processing gain.
Ri: The bit rate.
W: The chip rate of the W-CDMA (3.84 Mcps)
ρi: The required Eb/No for the mobile i and for a certain service quality.
vi: the average voice activity factor indicating the portion of time when the user is actively transmitting. [1-2]

Using the above definitions, the total interference parameters required for the performance analysis can easily design as follows:

Let Δni is called load factor increment for the new user i therefore,

$$\Delta ni = 1 / [(Gi/ \rho i) + 1] \quad (2)$$

The total load factor n of such an interference system is the sum of the load factor increments by N active users. Therefore,

Where f is interference factor and every user has the same service rate, we can calculate the maximum number of simultaneously active users that can be permitted as:

$$N = 1 + nG/\rho v\,(1+f) \quad (4)$$

When the system is fully loaded, it has reached pole capacity or the maximum theoretical capacity of WCDMA system. Letting the n $\approx$ 1 in above equation yields:

$$N_{pole} = 1 + G/\rho v\,(1+f) \quad (5)$$

It accepts the new connection only if the following inequality is satisfied,

$$ni + n \leq nThr\ i \quad (6)$$

Where ni is the current load of the cell and nThr i is the load threshold.

The GoS is considered here to evaluate the system performance and defined as:

$$GoSj = \alpha * Phj + Pnj \quad (7)$$

Where Phb, i is the hand-off blocking probability, and Pnb,i is the new call blocking probability of calls belonging to traffic of type j. α = 10, represents priority level for hand-off call to new call. Smaller GoS means better system performance. The system capacity is evaluated using the total carried traffic. The total carried traffic is evaluated using: [1-2]

$$CT = [\lambda h1\,(1-Ph1) + \lambda h2\,(1-Ph2) + \lambda h3\,(1-Ph3)] + [\lambda n1\,(1-Pn1) + \lambda n2\,(1-Pn2) + \lambda n3\,(1-Pn3)] \quad (8)$$

I CAC AND PROPOSED WORK

Call Admission Control (CAC) is a strategy used to limit the number of call connections into the network in order to reduce network congestion, therefore enabling the system to provide the desired QoS to newly incoming and existing calls. Call admission control (CAC) is one of the key elements in ensuring the quality of service (QoS) in mobile/cellular wireless networks. The traditional trunk reservation policy and its numerous variants give preferential treatment to the handoff calls over new arrivals by reserving a number of radio channels exclusively for handoffs. Such schemes, however, cannot adapt to changes in traffic pattern due to the static nature. [8]

CAC is such a provisioning strategy to limit the number of call connections into the networks in order to reduce the network congestion, call blocking and call dropping. A good CAC scheme has to balance the call blocking and call dropping in order to provide the desired QoS requirements. CAC for high-speed wireless cellular networks has been intensively studied in the last few years. Due to users' mobility, CAC becomes much more complicated in wireless cellular networks. An accepted call that has not completed in the current cell may have to be handed-off to another cell. During the process, the call may not be able to gain a channel in the new cell to continue its service due to the limited resource in wireless cellular networks, which will lead to the call dropping. Thus, the new calls and hand-off calls have to be treated differently in terms of resource allocation. [3-4]

The CAC should consider that an accepted call can be forced terminated before completion of service, which is more unbearable to users than blocking of service. The telegraphic performance metrics, considered by CAC, are as follows.

- Carried Load: This metric represents the ratio of the bandwidth used by completely serviced calls to the total capacity of mobile cellular network. If a call is forced-terminated, the bandwidth used by the call is not taken into account.
- Call Dropping Probability: It is the probability that an accepted call is forced-terminated before it completes the service.
- Call Blocking Probability: It means the likelihood that a newly arriving call is blocked. Actually it depends on the CAC schemes.
- Call Completion Probability: It means the probability that a newly arriving call completes its service without forced termination.
- Handoff Failure Probability: It is the probability that a handoff fails because the target cell has no free channel. This is also called as forced termination probability.

Several CAC schemes have been developed in wireless cellular networks. Some of them are based on a predetermined maximum number of users in the system. Many schemes are more CDMA-oriented and consider the SIR as the determinant parameter in accepting or not accepting a new call. Those schemes are commonly called Interference-CAC (I-CAC) and can be further classified into: [1-2]

A *Wideband power based CAC*

This scheme computes the increase in the interference (power) caused by the establishment of a new user in the cell and accepts the call only if the total interference does not exceed a predefined threshold.

B *Throughput-based CAC*

A throughput-based CAC scheme computes the increase in the load caused by the establishment of a new user in the cell and accepts the call only if the total load does not exceed a predefined threshold.

C *Signal to noise interference ratio-based CAC*

This scheme computes the minimum required power for new user and accept it if is not below a predefined minimum link quality level.

D *Proposed scheme*

Our scheme differs from those schemes in terms of using the cell load as an admission criteria and also using queuing as an additional priority techniques for each class of hand-off calls. Also, the hand-off calls are divided into three individual classes (data, voice and video) each has its own QoS requirements. Maximum queue limit for each type of service class is five while the queuing time of each handoff calls class is exponentially distributed with mean. Our CAC scheme gives preferential treatment to high priority calls, such as handoff calls, by reserving some bandwidth to reduce hand-off failures. In addition, queuing is also used to enhance the hand-off success probability. Each type has three classes, newly originating calls and handoff calls. The handoff calls have higher priority than new calls. The system contains a separate queue for each handoff calls. The scheme uses the effective load as an admission criterion and applies different thresholds for new and hand-off calls. Finally, our study considers three types of class services: data, voice and video with their hand-off respectively.

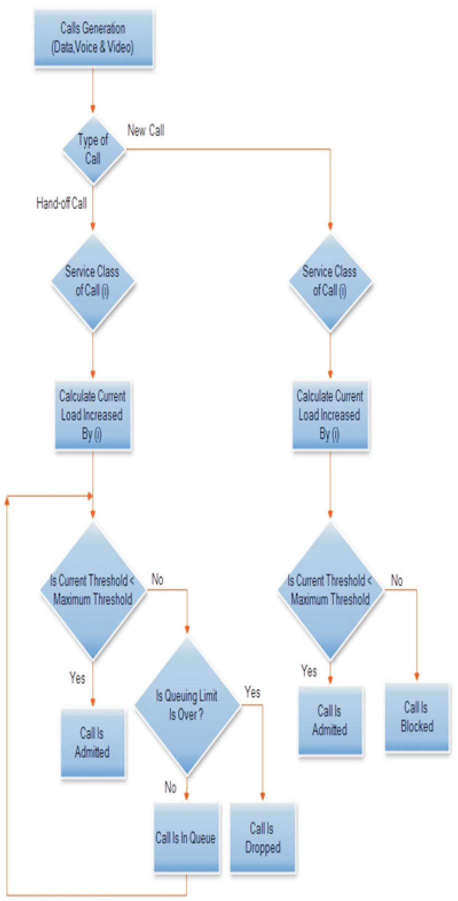

Fig. 1 Call Admission Control (CAC) Scheme (Proposed)

This CAC scheme has the following flow: when a call arrives, load factor threshold for new and hand-off calls and QoS requirements are determined firstly. Then the load increase of the arrived call and the current cell load factor before accepting the arrived call are calculated. After calculating the current load of the target cell i, it is compared with the load factor threshold of the arrived call of type i. If the current cell load factor plus the load increase is less than or equal the required load factor threshold for the arrived call, then the arrived call can be admitted to enter the target cell. Otherwise, the arrived call is queued or rejected based on queue availability. Queued hand-off calls can be accepted if sufficient bandwidth gets available, or can be terminated due to timeout. [1-2]

IV. SIMULATION RESULTS AND DISCUSSION

Proposed scheme is evaluated based on three QoS key points: The blocking probability for newly originating calls, the forced termination probability and the total system carried traffic. The blocking probability is the probability that a new call is denied access to the system, while the forced termination probability is the probability that a call that has been admitted will be terminated prior to the call's completion.

New calls and hand-off calls are treated differently. Hand-off calls are given higher priority to new calls, and load factor threshold for hand-off calls and new calls are also different. In simulation we go through the following different scenarios:

A *Scenario-1*

All call services classes (new calls and hand-off calls) are treated equally where they have the same load threshold and no queuing is used.

B *Scenario-2*

Same as 1, and in addition to that, the hand-off calls are allowed to be queued till the resource is available or the time out is reached.

C *Scenario-3*

(Proposed scheme) Same as 2, and in addition to that, the hand-off calls have higher load threshold than new calls. This scenario is repeated using different channel holding times. [1-2].

The arrival of new and hand-off calls is using poisson arrival process. Average service time for all services is 180 seconds. Arriving rates of all services are changed. Scenario-3 is repeated using different service times 120 sec and 90sec respectively. Fig. 2 represents the data GoS vs. offered data calls, Fig. 3

represents the voice GoS vs. offered voice calls and Fig. 4 represents the video GoS vs. offered video calls. From these figures, it is clear that the performance improves as we use the queuing technique. Also, as the channel holding time decreases the system performance increases. So as the service time decreases the waiting/queued calls will have better chance to get the channel before they timed out. Smaller GoS means will get better system performance and hence the system performance is improved due to smaller GoS as the service time decreases shown in Fig. 2, Fig. 3 and Fig. 4 respectively. Fig. 5 represents the system carried traffic vs. the offered traffic. The system has less carried traffic in Scenario-1. But it is significantly increases in Scenario-2 and Scenario-3 as the channel holding time decreases shown in Fig. 5. So as the carried traffic increases the system capacity in term of supporting more calls increases.

TABLE I
PARAMETERS FOR SIMULATION

Parameter	Value
Access Mode	W-CDMA (FDD)
Bandwidth	5 MHz
Chip Rare	3.84 Mcps
Service classes	Video, Data and Voice
Bit rates	Voice: 12.2kbps, Data: 144 kbps, Video: 384 kbps
Eb/No	Voice :5.6dB, Data: 3.2 dB, Video:1 dB
Activity	Voice : 0.4, Data: 1, Video: 1
Fractional load	60-65%
Interference factor (f)	0.5
Arrival rate	Poisson (0.2-2 calls/sec)
Channel holding time	180 Seconds
Queue limit	Max. 5
Queuing time	15 Seconds (Exponential)

It is clear that our proposed scheme has better system capacity and this improvements increase as channel holding time decreases. In general as shown in these figures, the system has a better performance by reducing the blocking and dropping probability of new and hand-off calls and increases the total system carried capacity under this proposed scheme.

Three types of services are considered, video, data and voice. Each type has two classes, newly originating calls and soft handoff calls. The soft handoff calls have higher priority than new calls by using a soft load factor margin and by implementing queuing techniques. The system contains a separate queue for each handoff calls type and a predetermined load threshold. To prioritize the soft handoff calls, a certain amount of cell load is reserved exclusively soft handoff calls. In addition, queuing is also used to enhance the handoff success probability.

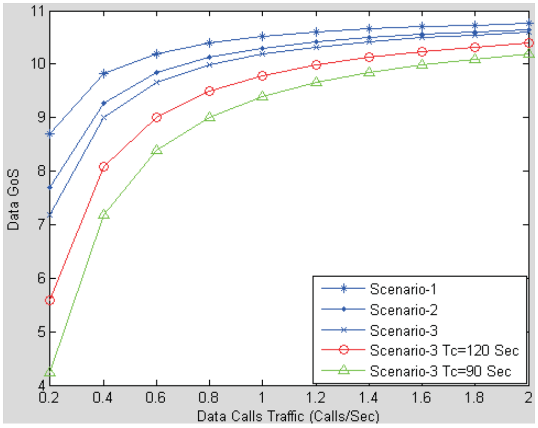

Fig. 2 GoS for Data Calls (Data GoS vs. Offered Data Calls/Sec)

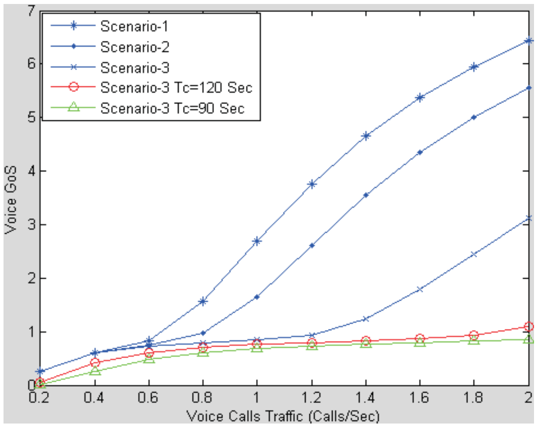

Fig. 3 GoS for voice calls (Voice GoS vs. Offered Voice Calls/Sec)

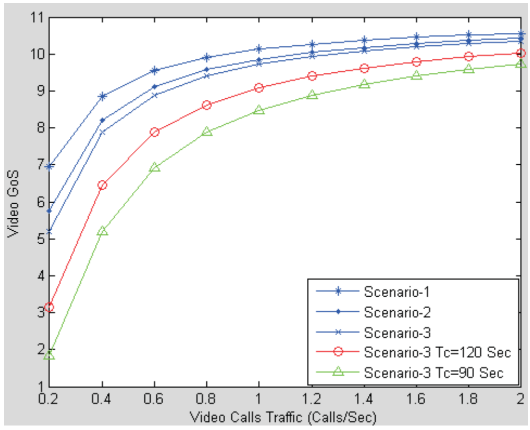

Fig. 4 GoS for video calls (Video GoS vs. Offered Video Calls/Sec)

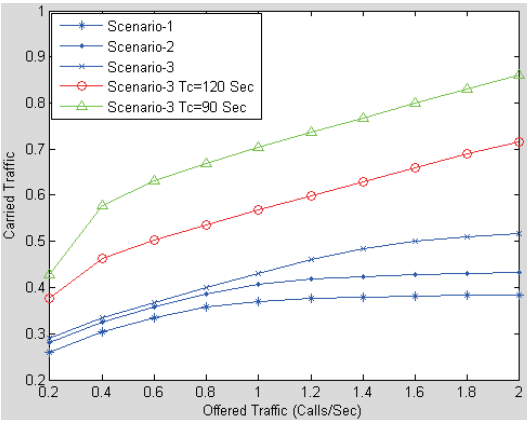

Fig. 5 System Carried Traffic (Carried Traffic vs. Offered Traffic)

For the call arrival rate 0.4 calls per sec, the channel holding/service time for (voice, data & video) hand-off call, are 150 sec, 150 sec & 180 sec respectively with bit rates are 12.2 kbps, 64 kbps & 48 kbps respectively. As the queuing time is 15 seconds, each type of call in each class has to wait 15 seconds to get the channel for their admission & if the call get channel within the time provided for queue then the system will have provide a good QoS to user. Following table shows that incoming call will stay in queue & it will get channel before the time out is reached, also the average queue time of waiting call for getting the channel is less than 15 second in each class. Hence the system has a better performance by reducing the dropping probability of hand-off calls and increases the total system carried capacity under this queuing scheme.

TABLE 2
QUEUING RESULTS

Call Type	Time of Call (Sec) Admitted in Queue	Time of Call (Sec) Admitted in CAC/System	Time of Call (Sec) Stay in Queue	Average Time of Call (Sec) in Queue
Voice	167.09	179.94	12.85	13.19
Voice	254.42	267.95	13.54	
Data	175.70	184.26	8.55	7.20
Data	180.56	186.40	5.84	
Video	179.94	184.26	4.31	3.99
Video	226.14	229.80	3.66	

V.CONCLUSION

CAC research remains an exciting area. The state of the art in CAC suggests that many CAC schemes may not handle the challenges about multimedia services in wireless cellular networks for the provision of QoS due to their different QoS requirements. Few CAC schemes try to maintain the QoS in wireless cellular networks but each one of them has its own advantages and disadvantages.

We propose QoS based CAC scheme for a 3G wireless cellular network for the provision of QoS. Our proposed scheme is prioritized based hence for giving the priority to hand-off calls over new calls; we introduce queuing technique because our main focus is to reduce the hand-off failures. Also the performance analysis of the scheme through simulation with different scenarios is became a keynote of our study. Finally we conclude that our scheme reduces the drop hand-off calls and increases the total system capacity; hence the QoS and the system performance can significantly be enhanced.

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