Reservation Based Adaptive Uplink Admission Control for WCDMA

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***Abstract*-An uplink admission control algorithm suitable for Wideband Code Division Multiple Access (WCDMA) is presented in this paper. The proposed algorithm gives preferential treatment to high priority calls by pre-reserving certain amount of interference margin. The algorithm uses auto-tuning approach to dynamically change the allowable interference limit. The algorithm is tested by simulation using a service model which considers both mobility of users and diversity of services. The results, obtained by applying the proposed and an already established algorithm, are compared and analyzed to demonstrate the improvements in performance of the system.**

I. Introduction

The Admission Control (AC) module in Wideband Code Division Multiple Access (WCDMA) network decides whether a new user will be allowed to have a particular service at a particular time. Special attention is given to AC in WCDMA because here the system capacity is not hard limited as in Second Generation (2G) Time Division Multiple Access (TDMA) or Frequency Division Multiple Access (FDMA) wireless systems. The system capacity is limited by the maximum tolerable interference in the system.

Although the main objective of AC module is to limit the system interference, another goal of admission control is to provide better service to high priority calls and guaranteeing certain levels of quality of service (QoS) to various service classes. These requirements also affect the performance of the AC algorithm. Based on the users' priority, bit rate requirements, mobility etc. the AC module has to decide which user gets preferential treatment than others.

The proposed algorithm takes the system interference as the guiding factor to decide when to admit a new call and when to reject one. It uses one of the two different strategies for adjusting interference threshold. (The process of adjusting threshold is called auto-tuning.) It also uses a reservation scheme to give better service to high priority users. Lastly, we propose a conditional reservation scheme for coping up with various situations. The performance of AC algorithm has been evaluated through simulation. The results and related comparisons are presented later in this paper.

II. Related Research

In [12] uplink direction of AC is considered. The author used the total received power at the base stations as a guide to determine the system condition. A threshold for the total received power is estimated and auto-tuned by gathering different statistics (e.g. proportion of blocked, dropped and bad calls) from the system operation. However, the author did not use any reservation scheme and the auto-tuning approach used there had some drawbacks. In [10] the main focus was to propose and evaluate four different measures to estimate the uplink noise rise. The authors showed that as the system load increases, the uplink interference tends to become infinity. So, one must control the uplink load so that system remains in a stable state. In [13] the authors proposed two AC strategies based on global and local information. The global AC uses information from all the cells for admission of a new call but has an intensive computational complexity. On the other hand, the implementation of local AC algorithm in each cell uses only local information and only requires the number of calls currently active in that cell and thus is very simple to implement. In [2] the authors proposed interference guard margin scheme for admission control in WCDMA system. Their proposed AC algorithm gives preferential treatment to high priority calls, such as handoff calls, by pre-reserving a certain amount of channel margin. The algorithm dynamically adjusts the level of margin by referencing traffic conditions in neighboring cells. According to [9], the power level received at the base station is the indication of system condition. The main objective of their algorithms is to keep the received power level at the base station under maximum allowable power limit. They assumed that the maximum received power at a base station is limited to some constant value for each class of users. Based on the desired quality of service target for a new call, the algorithm calculates the total power level that will be added to the system and accepts it if the maximum threshold set for that user's class is not exceeded.

III. Admission Control For Uplink

Interference based uplink admission control strategies are described in [7]. The basic idea is simple. A new radio access bearer is not admitted if:

$$P_{rx\_total} + \Delta P_{rx\_total} > P_{rx\_target} \quad (1)$$

in which P_{rx_total} represents total uplink interference present in the cell (which includes intra-cell interference, inter-cell interference and background noise), ΔP_{rx_total} represents uplink interference increase due to the new call and P_{rx_target} represents target threshold for total interference.

Pollonen in [12] has derived the following equation for determining the increase in interference power due to a new user request

$$\Delta P_{rx\_total} = \frac{P_{rx\_total}}{1-\eta-\Delta\eta}\Delta\eta \quad (2)$$

where η (called load factor) is a measure of network congestion defined as follows

$$\eta = 1 - \frac{P_n}{P_{rx\_total}} \quad (3)$$

Here P_n is the background noise. The expression for load factor of one user, L_j, has been derived in [8] and it is obtained as

$$L_j = \Delta\eta = \frac{1}{1+\frac{G_p}{(E_b/N_0)_j \cdot \upsilon_j}} \quad (4)$$

where G_p is the processing gain, υ_j is the channel activity factor of the user and E_b/N_0 is the required energy per bit to noise power density ratio. Using (2), (3), (4), ΔP_{rx_total} can be determined which is used in (1) for call admission decision.

Because of interference limited nature of WCDMA, P_{rx_target} must be set properly. If it is too high, the ongoing and newly admitted calls will suffer from low quality. Again, if it is too low, the resource will remain underutilized. One solution of this problem is to set P_{rx_target} dynamically based on QoS. Four important metrics for this purpose are :- (i) P_{drop}-the proportion of admitted calls that has been dropped due to too much error, (ii) P_{bad}-proportion of calls whose frame error rate exceeds the acceptable level, (iii) P_{block}-proportion of new calls that is not admitted into the system and (iv)$P_{hand\text{-}off\ failure}$-proportion of calls that has been dropped during hand-off. The strategies followed in this paper for setting P_{rx_target} dynamically are (1) GoS (Grade of Service) based strategy and (2) Policy based strategy.

A. GoS Based Strategy (GBS)

A GoS based auto-tuning strategy is proposed in [14]. The basic idea is to define a cost function, GoS, as:

$$GoS = A \times P_{drop} + B \times P_{bad} + C \times P_{block} + D \times P_{hand\text{-}off\ failure} \quad (5)$$

It is clear from the equation that a low value of GoS indicates good performance and vice versa. So, our target is to reach the minimum point of GoS curve.

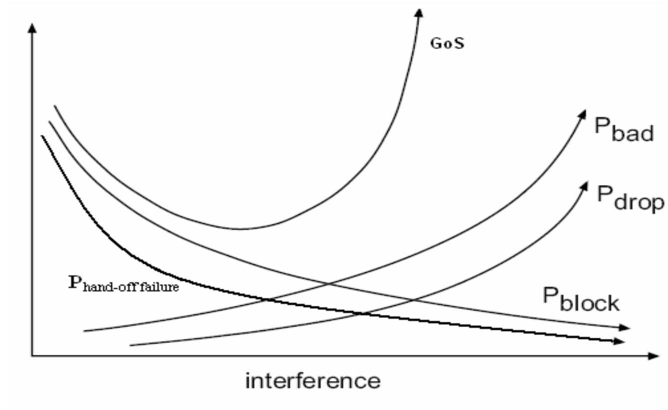

Fig. 1. GoS, P_{drop}, P_{bad}, $P_{hand\text{-}off\ failure}$, P_{block} as a function of interference.

Equation similar to (5) is also used in [4], [10], [12]. The coefficients A, B, C, D are chosen properly to give appropriate weight to the various performance metrics. The interference target is changed dynamically to minimize the cost function on cell basis. Thus P_{rx_target} of the cell is increased if

$$\frac{d(GoS)}{dP_{rx\_target}} < 0, P_{rx\_ave} > P_{rx\_target} - \Delta \quad (6)$$

where Δ represents an infinitesimal small positive number and P_{rx_ave} represents average value of P_{rx_total}. Δ is used in the second constraint to guarantee that the cell is heavily loaded. Similarly, P_{rx_target} is decreased if

$$\frac{d(GoS)}{dP_{rx\_target}} > 0, P_{rx\_ave} > P_{rx\_target} - \Delta \quad (7)$$

To prevent P_{rx_target} from taking too low or too high a value, a minimum and maximum value of target has been set ahead (based on network planning). These ensure minimum capacity and coverage.

One problem of this approach is that it works best for known load. Coefficients A, B, C, D can be chosen to yield optimum performance at that load. At varying load the approach does not work well. Our proposed strategy chooses the value of A, B, C, D dynamically based on load factor i.e. instead of using constant values, the values of A, B, C, D are taken from functions of load factor, η. The functions are carefully chosen so that the highest precedence is given to dropped and bad calls (i.e. A and B) at every condition of loading but relative precedence of blocked and hand-off failure calls (i.e. C and D) is higher at high load than that of low and moderate load. So our proposed GoS is

$$GoS = A(\eta) \times P_{drop} + B(\eta) \times P_{bad} + C(\eta) \times P_{block} + D(\eta) \times P_{hand\text{-}off\ failure} \quad (8)$$

B. Policy Based Strategy (PBS)

Another straight forward approach of auto-tuning is to implement business policy of the mobile operator directly. In this case the company sets acceptable levels of P_{drop}, P_{bad}, P_{block}, $P_{hand\text{-}off\ failure}$. For auto-tuning, the algorithm first determines the performance metric whose value is more intolerable than others and then it changes (increases or decreases) the value of P_{rx_target} to make that performance metric tolerable.

Let the ranges of metric M_i be $[0.0, M_{i1})$, $[M_{i1}, M_{i2})\ldots[M_{i(N-1)}, M_{iN})$ and $[M_{iN}, 1.0]$. The interpretation of these ranges is that the lowest range is fully tolerable and the highest range is extremely intolerable. Intermediate ranges represent different degrees of tolerance. To express the variation of the degrees of tolerance of different ranges, each range is assigned a positive value called Range Value (RV). Higher value means more intolerable range. For auto-tuning, first the ranges, where the current values of different metrics lie, are determined. Then for each metric, the RV's of different classes of service are summed. The metric yielding the maximum sum is the decision making metric. P_{rx_target} is then adjusted based on value of that metric. Thus the algorithm is

For each class of service
  For each of P_{drop}, P_{bad}, $P_{hand\text{-}off\,failure}$ and P_{block}
    Determine RV of the range where the metric lies
  End For
End For
For each of P_{drop}, P_{bad}, $P_{hand\text{-}off\,failure}$ and P_{block}
  Sum the RV of different classes of service
End For
Find the metric whose sum is the maximum and adjust P_{rx_target} depending on that metric

To incorporate load variation, different ranges may be used for different conditions of loading.

C. Reservation Scheme (RS)

Different services of WCDMA have different price rates. Users, who pay more, should be given more priority. Our proposed strategy reserves a certain portion of P_{rx_target} for a particular class of service based on that class's priority, call arrival profile and bandwidth requirement. Let f_i be the fraction of total calls that are of Class i type, B_i be the bandwidth requirement of Class i and p_i is the priority of Class i. Then fraction of P_{rx_target} reserved for Class i is

$$R_i = \frac{f_i \cdot B_i \cdot p_i}{\sum f_j \cdot B_j \cdot p_j} \quad (9)$$

This calculation is done periodically on cell basis to make R_i dynamic. Now a call of Class i will be admitted if

$$P_{rx\_total\,for\,class\,i} + \Delta P_{rx} \leq R_i \times P_{rx\_target} \quad (10)$$

D. Conditional Reservation

RS increases blocking and hand-off failure probability of low priority classes. At high load, when there is a scarcity of system resources, it seems plausible. But at low load, when there is enough resource to improve blocking and hand-off failure probability of low priority classes, RS may lead to poor performance. Therefore, our proposed algorithm uses RS at high load and no reservation at low load.

IV. SIMULATION RESULTS AND ANALYSES

Two classes are considered with different priority and bandwidth requirement. Class 1 represents circuit switched voice data (high priority) and Class 2 represents packet switched interactive traffic (low priority).

TABLE 1. SIMULATION PARAMETERS

Parameter Name	Value	Parameter Name	Value
WCDMA chip rate	3.84 Mcps	Class 1 information bandwidth	19.2 kbps
Channel activity factor	1	Class 2 information bandwidth	38.4 kbps
System Bandwidth	5 MHz	No. of cells	7

A. System Loading

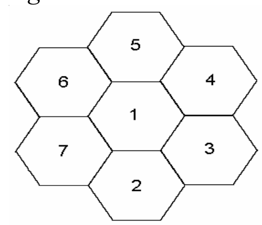

Fig. 2. Cell configuration.

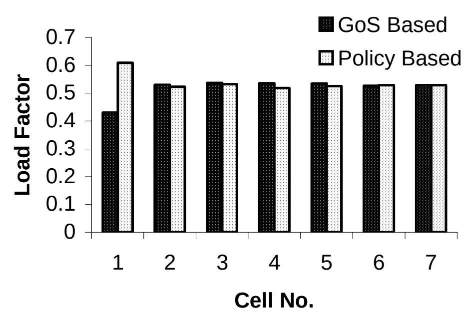

Fig. 3. Load Factor vs. Cell No.

Fig. 3, shows that all the cells in the network are moderately loaded in both strategies. But loading of $cell_1$ is higher in PBS compared to that of GBS. This occurs because $cell_1$ has the highest number of hand-off calls and PBS (for its chosen levels of performance metrics) puts slightly more emphasis on blocked and hand-off calls than GBS.

B. Call Conditions for Different Classes of Service

In the simulation, the call conditions of any particular class is observed by varying its inter arrival time while keeping the inter arrival time of other class fixed.

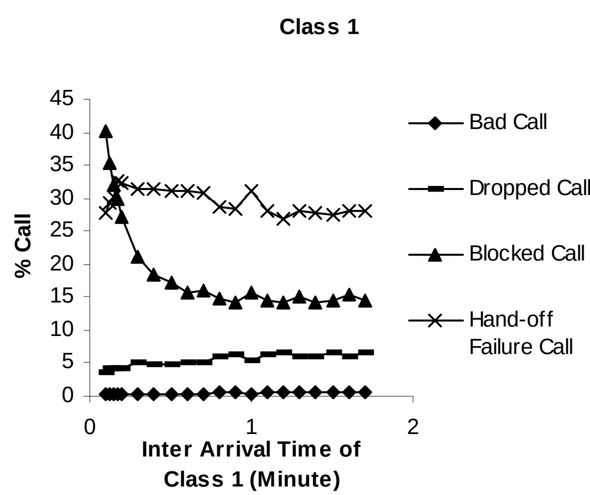

Fig. 4. Call conditions for Class 1 for GBS.

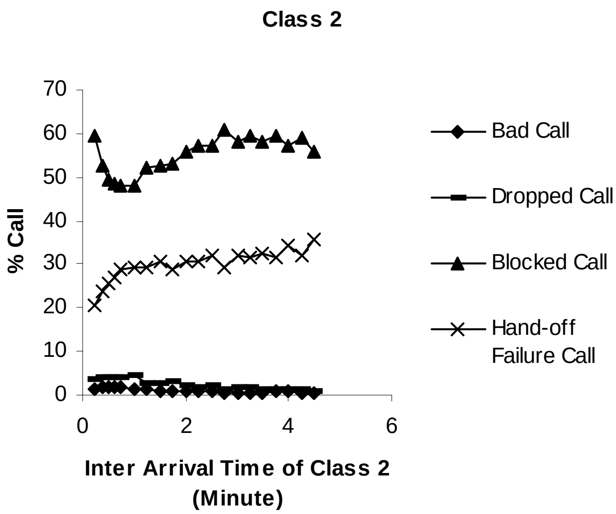

Fig. 5. Call conditions for Class 2 for GBS.

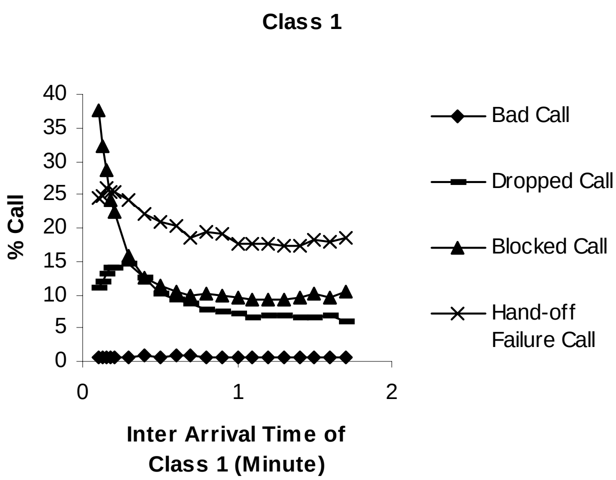

Fig. 6. Call conditions for Class 1 for PBS.

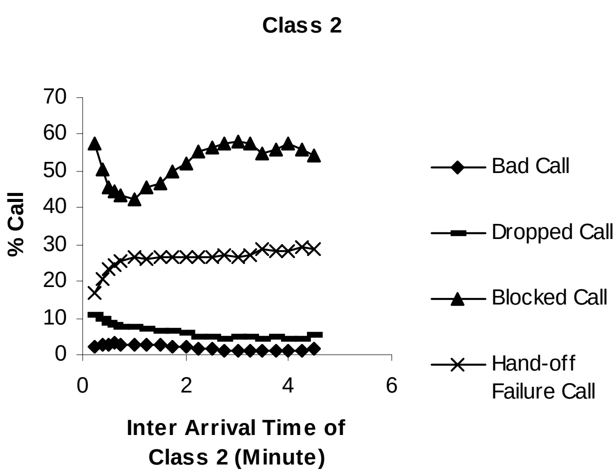

Fig. 7. Call conditions for Class 2 for PBS.

In Fig. 4 and 6, for Class 1, the percentages of blocked and hand-off failure calls are showing their trivial nature i.e., their values increase (with some irregularity) with the decrease of the inter arrival time and vice verse. Dropped and bad calls do not vary much because they are given highest precedence. GBS puts more emphasis on bad and dropped calls than PBS. That is why percentages of bad and dropped calls are higher in PBS than those in GBS and they have a tendency to rise initially in PBS.

Fig. 5 and 7 related to Class 2 show that hand-off failure rate increases slightly with the increase in inter arrival time. The reasons behind this are the reservation scheme and the lower priority of Class 2. When arrival rate of Class 2 decreases, the proportion of total power reserved for Class 1 increases because of its higher priority and unchanged arrival rate. This results in smaller reservation for Class 2 calls, which causes the above observation. Blocked calls initially decrease and then increase because initially increase in inter arrival time has the dominant effect and then decrease in reservation has the dominant effect. The other call conditions do not vary much because they have the highest priority.

C. Performance Comparison

In the simulation, the system performance is measured using the following functions to compare the performance of the proposed strategies with Pollonen's algorithm in [12]:

$$W = (1 - P_{drop}) \times 10 + (1 - P_{bad}) \times 5 + (1 - P_{block}) \times 2 + (1 - P_{hand\_off failure}) \times 3 \quad (11)$$

$$F = W \times LoadFactor \quad (12)$$

A higher value of W indicates that the system is performing well as the amount of dropped, bad, blocked and hand-off failure calls are low. However this value does not reflect the system loading correctly. The value of W can be high if the system is lightly loaded. So in order to appraise the performance of the admission control algorithm properly, the system loading (i.e., Load Factor) must be incorporated in the final performance measure i.e., F. This ensures both proper utilization of system resources and effective management of the scarce radio spectrum. The comparison results are presented in Fig. 8.

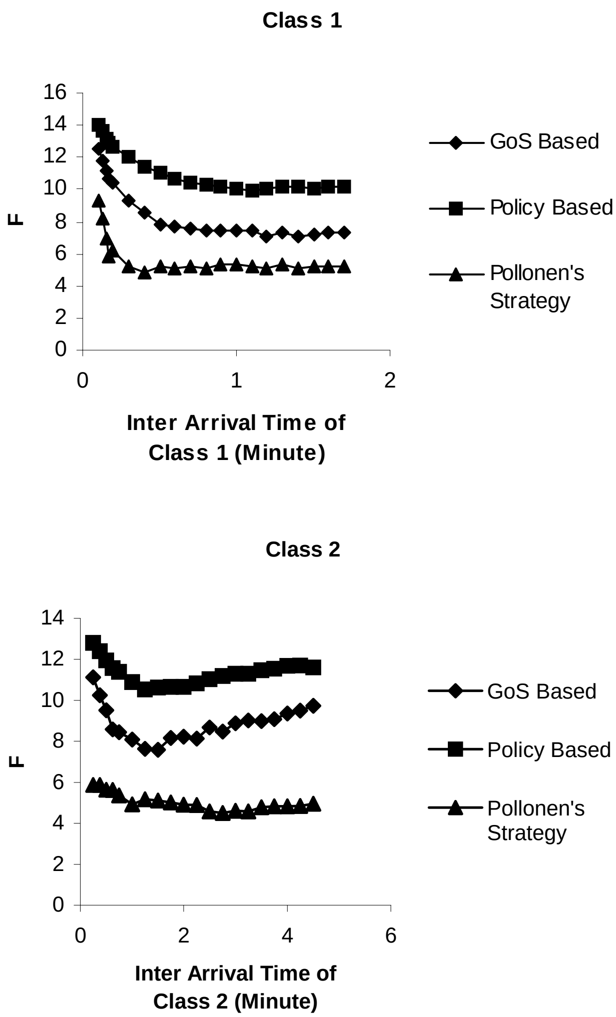

Fig. 8. F vs. Inter Arrival Time.

As previously stated, a higher value of F reflects both proper utilization and loading of the system and favorable user satisfaction. Fig. 8 clearly illustrates that the proposed algorithm in this paper performs better than the previous algorithm of Pollonen for both Class 1 and Class 2 because of better auto-tuning strategy and reservation scheme.

V. Conclusion

The algorithm presented in this paper is significant in the sense that it brings together the findings and benefits of previous works in this topic in one place and combines them in order to find a suitable balance between all of them. The algorithm tries to maximize the satisfaction of both the users and operators by using auto-tuning and reservation scheme. The performance analysis of this algorithm with a previous work clearly shows the improvement of this proposed algorithm. However, firm conclusions cannot be drawn through mere simulation regarding its actual performance in real network as it depends highly on network planning, dimensioning and environment.

In the conducted simulation, only two service classes were considered. But the proposed algorithm is structured to deal with multiple service classes.

This paper considers only uplink direction. With the explosion of multimedia services in mobile communication, more bandwidth will be required in the downlink compared to that of the uplink. So the downlink direction may become the next bottleneck in any cellular systems. Hence a study targeting downlink AC of WCDMA system should be performed to make the AC module more flexible and efficient. Studies should also be conducted for other radio resource management algorithms.

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