Fuzzy Based Power Control and TCP Aware Call Admission for WCDMA Network

N. Mohan, T. Ravichandran

Abstract - Fuzzy based power control and TCP aware call admission is necessary for the QoS provisioning in WCDMA environment. In this paper, we propose to design a new two level CAC algorithm with power control for multiple services like voice, video and data for multiclass users. It determines the optimum set of admissible users with optimum transmitting power level, so as to minimize the interference level and call rejection rate. In order to efficiently utilize the system resource from an admission control perspective, we propose a TCP-aware CAC scheme to regulate the packet-level dynamics of TCP flows for TCP type calls. We analyze the system performance under realistic scenarios in which (i) the call holding time for non-elastic traffic like voice is independent of system states and (ii) the call holding time for TCP type of traffic depends on the system state, i.e., on the TCP flow’s transmission rate. In addition to this, fuzzy based power control for multiple services like voice, video and data for multiclass users. It determines the optimum set of admissible users with optimum transmitting power level using fuzzy logic, so as to minimize the interference level and call rejection rate.

I. INTRODUCTION

Since the capacity of WCDMA is interference limited, the capacity will decrease when the number of users in the WCDMA system is increased. In order to maximize the system capacity, it is essential to minimize the interference in the systems. The transmission power from other users in the uplink is one of the vital sources of interference. A mobile nearby the base station may transmit excessive power, if the transmission power in the uplink is not properly controlled resulting in large interference to the further users connected to the same base station. This condition extensively reduces the system capacity and hence it is vital to control the transmitted power [15].

In CDMA, its performance gets directly affected since the system power control has a strong effect on the interference experienced by the receiver. The main characteristics of power control are compensation of fading channels and changes in the transmitted powers of interfering users. On the other hand, it might cause problems on the adaptation of equalizers [16].

A power control mechanism, which guarantees that the received power levels from all User Equipments (UE) are equal at the base station, can avoid the above issues [17]. The fundamental idea of power control mechanism is handling the minimum requirement for the Quality of Service (QoS) of the channel and to maximize the minimum signal to interference ratio (SIR) in each of the channels in the CDMA system [18]. Therefore power control is seen as an important method to reduce mutual interference between the users, at the same time compensating for time varying propagation conditions. It also decreases the transmission power and maximizes the system capacity [19].

TCP-aware CAC scheme to regulate the packet-level dynamics of TCP flows for TCP type calls. We analyze the system performance under realistic scenarios in which (i) the call holding time for non-elastic traffic like voice is independent of system states and (ii) the call holding time for TCP type of traffic depends on the system state.

It also contains an adaptive scheduling scheme to allocate optimum rate for each traffic queue and for minimizing the delay. The proposed scheme adapts for changing the traffic conditions based on estimation of future packet arrival rates.

II. RELATED WORK

Seong-Jun Oh et al. [4] have studied the radio resource allocation problem of distributed joint transmission power control and spreading gain allocation in a DS-CDMA mobile data network. The network consists of K base stations and M wireless data users. The data flows which are produced by the users are considered as best-effort traffic, in the sense that there are no prespecified restrictions on the quality of the radio channels. They are interested in designing a distributed algorithm that attains maximal (or near-maximal in some reasonable sense) aggregate throughput, subject to peak power constraints.

Young-Long Chen et al. [6] have proposed a method which combines the CAC and power control mechanisms and operates in a centralized control manner. The spirit of their centralized call admission control (CCAC) scheme was to merge the two mechanisms and to treat the call admission decision as an eigen-decomposition problem. In their method, a new call was attended only if the quality-of-service (QoS) requirements of all the active links in the network are maintained.

Jyoti Laxmi Mishra et al. [7] have evaluated various types of call admission control algorithm. The objective of their research was to improve the same algorithm with multiclass users and multiservice using fuzzy logic.

The fuzzy based CAC scheme for wideband CDMA cellular system, to meet the disputes in CAC due to user mobility, limited radio spectrum, heterogeneous and dynamic nature of multimedia traffic, and QoS constraints have been studied and its performance was examined by S. Malarkkan and V.C.Ravichandran[8]. The fuzzy approach overcomes measurement errors, mobility and traffic model uncertainty, and avoid the necessities of complex mathematical relations among various design parameters.
Nidhi Hegde and Eitan Altman [13] have designed a resource sharing of BE applications with the RT applications in WCDMA networks. Both the types of traffic have flexibility to adapt the obtainable bandwidth but not like the BE traffic. RT traffic requires strict minimum bounds on the throughput. They have examined the performance of both BE and RT traffic and examined the effect of reservation for some portions of the bandwidth for the BE applications. Also they have presented a novel capacity definition associated to the delay of BE traffic and showed how to calculate it.

S.P.V. Subba Rao et al. [20] have proposed an adaptive power control mechanism for multimedia traffic in WCDMA networks. In their proposed algorithm, they have used two latest Transmit Power Control (TPC) commands to compute the Adaptive Factor based on a predefined Adaptive Control Factor (ACF). They have also introduced another parameter called Power Determining Factor (PDF) based on the data traffic rate in order to determine the power. Based on their new parameter, the power was increased or decreased. Also, depending on the traffic rate, their PDF factor was updated such that if the observed traffic rate was high, then they would increase the parameter and subsequently increased the power. Suppose, if the traffic rate was low, then their parameter would be decreased and correspondingly the power too.

Markus Laner et al. [21] have analyzed the uncoded BER parameter, with respect to its possible contribution to an improvement of the uplink OLPC algorithm. Their research was performed by means of extensive measurements in a live network which proved that the actual implemented algorithm converged slowly. They have also founded that the reason was due to the QoS estimated by CRC and as the uncoded Bit Error Ratio (BER) hold information about the QoS, this parameter could be used to increase convergence speed of their OLPC. They have also presented a statistical model of the control path of the OLPC which considered the uncoded BER information.

III. FUZZY LOGIC BASED CALL ADMISSION CONTROL

a) Computation of Type of Service Request ($S_R$)
The type of service ($S_R$) taken in to account are of two types namely Real Time (RT) and Non Real Time (NRT). The Real Time services are provided with a high priority when compared with those of Non Real Time services.

$$S_R = \begin{cases} 1, & \text{For RT} \\ 0, & \text{For NRT} \end{cases} \quad (1)$$

b) Computation of Total Power ($P_T$)
The downlink power for $k^{th}$ user can be expressed as follows [25]

$$P_R^k = L_P^k \cdot P_{MS}^k$$

where $P_R^k$ is the downlink power of $k^{th}$ user, $L_P^k$ is the estimated path loss between $k^{th}$ MS and its serving BS, $P_{MS}^k$ is the transmit power allocated to $k^{th}$ MS by its serving BS

The total power of N number of users served by a single BS is given by the summation of each individual power of all the users such that

$$P_T = \sum_{k=1}^{N} L_P^k \cdot P_{MS}^k \quad (2)$$

c) Basic Concepts of Fuzzy logic
Fuzzy logic is a problem solving control system method that offers itself to implementation in systems. It can be implemented in hardware, software, or a combination of both. Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy logic is a form of many valued logic and it deals with reasoning that is fairly accurate rather than fixed and exact.

Fuzzy Congestion Controller (FCC) is a fuzzy logic controller (FLC). Designing a FLC involves selection of suitable mathematical representations for t-norm, s-norm, defuzzification operators, fuzzy implication functions and shapes of membership functions among a rich set of candidates.

Particular selection of these operators and functions alter the nonlinear input-output relationship or in other words, the behavior of a FLC. But, research has shown that same effects can be achieved by proper modification of the rule base. Therefore, in practical applications, usually computationally lighter and well studied operators and functions are selected, and desired behavior of a FLC is obtained by altering the linguistic rules.

d) Fuzzification
We will now describe our methodology of fuzzy logic based call admission control for WCDMA networks. The two most important variables taken in to account are Type of Service Request ($S_R$) and the Total Power ($P_T$). With fuzzy logic, we assign grade values to our three variables. Our fuzzy set therefore consists of three fuzzy variables

Fuzzy set = \{ $S_R$, $P_T$ \}

Fuzzy logic implements human experiences and preferences via membership functions and fuzzy rules. In this work, the fuzzy if-then rules consider the parameters: Type of Service Request ($S_R$) and the Total Power ($P_T$). The fuzzy logic uses two input variables and one output variable. The inputs are fuzzified, implicated, aggregated and defuzzified to get the output.

The inputs parameters are,

$S_R$: Type of service request (Real time or Non-real time)

$P_T$: Total Power.

The linguistic variables associated with the input variables are Low (L) and high (H).

The corresponding fuzzy linguistic term set is,

$F(S_R)$: \{ High-RT, Low-NRT \}

$F(P_T)$: \{ Low, High \}

The output variables use four linguistic variables SR, WR, WA and SA, where SR denotes acceptability of the new call is Strongly Rejected, WR denotes the acceptability of the new call is Weakly rejected, WA denotes the acceptability of the new call is Weakly Accepted and SA denotes the acceptability of the new call is Strongly Accepted. The output linguistic variable, denoting the acceptability of the new call is,

$F(D)$: \{ Strongly Rejected, Weakly rejected, Weakly Accept ed, Strongly Accepted \}

Fuzzy set = \{ $S_R$, $P_T$ \}
TABLE 1. FUZZY RULES USING SR AND PT

<table>
<thead>
<tr>
<th>Fuzzy Rule</th>
<th>Type of Service Request (Sr)</th>
<th>Total Power (Pt)</th>
<th>Fuzzy Decision (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>Low</td>
<td>WA</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>High</td>
<td>SR</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>High</td>
<td>WR</td>
</tr>
<tr>
<td>4</td>
<td>Low</td>
<td>Low</td>
<td>SA</td>
</tr>
</tbody>
</table>

e) Proposed Algorithm

When compared to call blocking, call dropping is worse. The main aim of the new call admission control algorithm is to reduce the load on the system while reducing the dropping rates.

Let $P_{tot}$ be the total power of the existing users $P_i, i = 1,2,..N$. Let $P_{ava}$ be the available total power. Let $L_{max}$ be the maximum overload of non-real-time traffic class.

1) new call request ‘m’ arrives
2) if enough resource available,
3) accept ‘m’
else, check.
4) if ($Sr > Pt$)
5) throw(TA)
6) else if ($Sr =< Pt$)
7) reject
8) else
9) throw(TA)

TA:
9.1) Perform TCP call adjustment for ‘m’
9.2) If BS has enough resource after TCP call adjustment. Then accept ‘m’
else, reject ‘m’
end

We apply the Service Degradation Descriptor (SDD) based on degradation mechanism [14], in which user calls are degraded as per the SDD of the user requirement. SDD is a number between 0 and 5. If the SDD is larger, then the willingness of the user/connection to be degraded is more and eventually dropped. The real time services are prioritized over the non-real time service which leads to reduced loss for real-time traffic classes. And we apply TCP aware call admission control scheme for local calls.

f) TCP Adjustment Algorithm

**Algorithm** TCP Aware CAC: Dynamic TCP Call Adjustment at Packet Level.

Require: $po(t), po_{U}, B, QoS$ profile of call ‘m’, $F_m$ is the average transmission rate of call ‘m’.

1) $z_1 ←$ the number of TCP call in the system
2) $\mu ←$ the total packet arrival rate
3) for $i = 1$ to $z_1$ do
4) /* reduce TCP call’s transmission rate */

$$\Delta \mu ← \frac{1}{RTT} \sqrt{\frac{3}{2p(t)}} - \frac{1}{RTT} \sqrt{\frac{3}{2p_U}}$$

5) $\mu ← \mu - \Delta \mu$
6) if $\mu + F_m ≤ B$, then
7) Accept ‘m’
8) Return “True”

9) end if
10) end for
11) Reject ‘m’
12) Return “False”

g) Service Degradation Descriptor

With user willingness to have their QoS profile degraded. To this end, a patented Service Degradation Descriptor (SDD) representing user willingness to be degraded [10] is used as an enabling QoS attribute for driving the integrated system in general and the power control in particular. SDD is a real number between 0 and 5. It describes how much the user is willing to get a degraded quality of service. The larger the SDD is, the more willing is the user to accept a degraded service and less the user is charged. A typical video telephony service can be degraded/adapted to current network conditions by using color/grey scale or by lowering the quality of the coded speech. Connection request that do not set a value for SDD, will have this value automatically set to a default service value by the network provider.

In WCDMA based 3G networks, Base stations implement closed loop power control at the level of the Radio Resource Manager (RRM) on which we are trying to improve by taking into account QoS profile as an extra parameter for power control. In effect, by proposing our QoS profile driven power control (QPC), we are superceding to the basic closed loop control in RRM. Indeed, a traditional RRM only takes into account channel gain when making a decision to control base transmit power. In implementing power control, we, however, take into account not only channel gain, but also the negotiated QoS requirements of existing users, namely the bit rate and the SDD representing willingness to be degraded. When, due to the problems cited above, congestion occurs at a cell, QPC is triggered to address the overload in power requirements. It is this entity that copes with the link degradation in WCDMA based 3G wireless networks, by using QoS profiles of the active mobile users.

Furthermore, when examining SHO requests QPC is also invoked to provide the necessary bandwidth for SHO requests.
that normally would not be accepted due to lack of resources/power.

IV. EXPERIMENTAL RESULTS

a) Simulation Setup
In this section, we simulate our proposed adaptive scheduling and call admission control algorithm in WCDMA cellular networks for admissible and non-admissible transmission scenarios. The simulation tool used is NS2 which is a general-purpose simulation tool that provides discrete event simulation of user defined networks. In the simulation, mobile nodes move in a 600 meter x 600 meter rectangular region for 50 seconds simulation time. Initial locations and movements of the nodes are obtained using the random waypoint (RWP) model of NS2. All nodes have the same transmission range of 250 meters. We compare our proposed power control based call admission (PCCA) scheme against the normal WCDMA scheme.

The simulation parameters are summarized in Table II.

Table II. Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Of Nodes</td>
<td>36</td>
</tr>
<tr>
<td>No. of Cells</td>
<td>6</td>
</tr>
<tr>
<td>Users per Cell</td>
<td>6</td>
</tr>
<tr>
<td>Slot Duration</td>
<td>2 msec</td>
</tr>
<tr>
<td>SINR threshold</td>
<td>5</td>
</tr>
<tr>
<td>Frame Length</td>
<td>3 slots</td>
</tr>
<tr>
<td>Txpower</td>
<td>0.66 w</td>
</tr>
<tr>
<td>RxPower</td>
<td>0.395 w</td>
</tr>
<tr>
<td>Routing Protocol</td>
<td>AODV</td>
</tr>
<tr>
<td>Speed of mobile</td>
<td>25 m/s</td>
</tr>
<tr>
<td>Traffic Model</td>
<td>CBR</td>
</tr>
</tbody>
</table>

b) Simulation Results

i) Based on Data Arrival Rate
In our first experiment, we vary the data arrival rate as 0.1, 0.2,...,0.5Mb.

![Figure 2](image)

**Figure 2. Arrival Rate Vs Throughput**

![Figure 3](image)

**Figure 3. Arrival Rate Vs Average Power**

![Figure 4](image)

**Figure 4. Arrival Rate Vs Call Blocking probability**

![Figure 5](image)

**Figure 5. Arrival Rate Vs End-to-End Delay**

Fig. 2 gives the average throughput measured. From the figure, it is clear that our PCCA scheme attains more throughputs when compared to the normal WCDMA scheme.

From fig. 3 and 4, we can observe that the proposed new PCCA algorithm has low average power consumption and low call blocking rate, respectively.

Since the adaptive scheduling algorithm tries to reduce the delay of each user class traffic which results from Fig. 5 indicate that the proposed scheme has less delay when compared with normal WCDMA.

ii) Based on User Class
In our next experiment, various user class traffic is varied as 1, 2, 3 and 4.

![Figure 6](image)

**Figure 6. Class Vs Call Blocking Probability**
Fig. 6 shows that for various user classes, the call blocking probability is reduced for the proposed scheme. Similarly, the end-to-end delay is also less in the case of the proposed scheme, which is observed from Fig. 7.

iii) Based On Number of Users
In our last experiment, the number of active users is varied as 2, 4, 6 and 8.

Fig. 8 and 9 shows the measured call blocking probability and throughput, respectively, when the users are increased. Clearly, our proposed scheme achieves reduced blocking probability and high throughput, when compared with the normal WCDMA scheme.

V. CONCLUSION

Usually based on the measured information’s like signal-to-interference ratio (SIR) or the total received power in the individual cells, conventional call admission control (CAC) methods accept or reject new incoming calls. But a new method is required to combine the CAC and fuzzy based power control mechanisms. For the traffic of non-stationary real-time classes at the base station, the performance of scheduler gets degraded due to the presence of arrival rate estimation errors, resulting in inefficient resource distributions and unequal delay variations from the targets. In this paper, we have designed a new CAC algorithm with fuzzy based power control for multiple services like voice, video and data for multiclass users. It determines the optimum set of admissible users with optimum transmitting power level so as to minimize the interference level and call rejection rate.

TCP congestion algorithm will exhaust all the available bandwidth until packet loss occurs. In order to effectively utilize the elastic feature of TCP applications, we have proposed a TCP-AIMD aware CAC scheme based on a two-level framework that takes both the call-level and the packet-level dynamics directly into account. The scheme is general enough and can be tailored to cope with specific packet switched wireless networks with proper modifications.

To allocate the optimum power for each traffic queue, fuzzy based power control method is proposed. By simulation experiments, we have shown that the proposed algorithms achieve reduced call blocking probability, optimum rate, reduced delay and reduced power.

VI. REFERENCES


Fuzzy Based Power Control and TCP Aware Call Admission for WCDMA Network

Heraklion, Greece, 2008.


