Functional Evaluation for Wireless Multimedia Networks by MAC Protocols

Rajeev Ranjan, Praveen Dhyani, Rajeev Kumar, Prashant Singh Rathore

Abstract:

A high capacity energy efficient dynamic MAC Protocol was developed for WCDMA wireless multimedia networks. It used multiple slots per frame allowing a multiple users to transmit simultaneously using their own CDMA codes. An adaptive power control algorithm was applied to reduce transmission power to maximize system capacity at the beginning of each frame. Result based on simulation revealed that proposed MAC protocol achieved high throughput and improved capacity.

Keywords- WCDMA, MAC Protocol, Transmit Power Control, High Capacity Energy efficient Dynamic MAC protocol, Adaptive Control Factor

Abbreviations- ACF- Adaptive Control Factor, HCEEDM-High Capacity Energy efficient Dynamic MAC protocol, LDT -low data traffic, WCDMA-Wideband code-division multiple-access.

I. INTRODUCTION

Wideband code-division multiple-access (WCDMA) forms the basis of the air interface in the 3rd generation cellular mobile communications. It has higher speeds and it supports more users as it utilizes the direct-sequence spread spectrum method of asynchronous code division multiple accesses. WCDMA is a wide band spread- spectrum channel access method and is a type of 3G cellular network. WCDMA has greater capacity than existing multiple access methods and its capacity can be improved by varying power and rate control. WCDMA systems are characterized as being interference limited. If there are a large number of users, then the mutual interference between the connections degrades the QoS for the new user as well for the ongoing connections. Reducing the interference in this system would increase in the system capacity.

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Rekha Patil and A. Damodaram with have proposed joint scheduling for admission and power control algorithm. But CAC alone is not enough to provide most optimal resource utilizations. So MAC algorithm which has efficient packet scheduler is necessary to be combined with an admission controller. Roobol et al have proposed a RLC/MAC protocol based on power control algorithm. Different reservation procedures and transmission modes are used for different traffic types. N. Mohan and T. Ravichandran has proposed a new CAC algorithm with power control and adaptive scheduling scheme. The power control algorithm is not adaptive. None of the above protocols addressed the issue of increasing the capacity of the network. Hence there is an urgent need to develop a High Capacity Energy efficient Dynamic MAC protocol (HCEEDMAC) to improve the capacity using power and congestion control and to allocate system resources to multimedia users for QOS provisioning and for high resource utilization. The operation of proposed MAC protocol is as follows. Users are admitted into the network based on Adaptive Call admission control algorithm. The algorithm reduces the blocking probability. After entering in the network users are transmitting data in the network by WCDMA scheduling and an adaptive power control algorithm is applied to reduce the average transmission power and to maximize the capacity.

The paper is organized as follows: In section II we explain dynamic MAC protocol with adaptive power control for wireless multimedia networks. In section III Capacity equation for WCDMA networks is derived. Section IV discusses Adaptive call admission control algorithm. Section V discusses simulation results. The paper is concluded in section VI.

II. DYNAMIC MAC PROTOCOL WITH WCDMA SCHEDULING AND ADAPTIVE POWER CONTROL

WCDMA SCHEDULING

In dynamic MAC, traffic is classified as Real time (RT) and Non Real time (NRT) and prioritized as High and low, respectively. For the high priority data traffic, a node can be in one of two modes: low data traffic (LDT) or high data traffic (HDT). A node is in HDT only when it receives a High Contention (HC) Message (HCM) from a two-hop neighbour within the last T period. Otherwise, the node is in LDT. A node sends an HCM when it experiences high contention due to high data traffic. Each node calculates the data traffic (DT) to calculate the contention. If DT is more than a threshold value DTth, then the nodes will send a HCM. In LDT, any node can compete to transmit in any slot, but in HDT, only the owners of the current slot and their one-hop neighbours are allowed to compete for the channel access. In both modes, the owners have higher priority over non-owners. If a slot does not contain an owner or its owner does not have data to send, non-owners can transmit their data in this slot.

Each node calculates the traffic by using the traditional way to calculate the system capacity for data traffic, traffic, which is given by; (*DT)*

$$DT = \left[\frac{\beta p}{SIR}\right] \times \frac{1}{1+K} \times p \times \frac{1}{\phi} \times \beta\alpha \qquad (1)$$

Where *p*β *a*β, and = the processing gain by spectrum spreading and gain due to sector antenna respectively.

SIR = Signal to interference ratio

κ = The interference from other nodes

P = The power control factor

Φ = The voice/data activity factor

The time is divided into fixed size frames in the proposed protocol. A frame has N time slots for the purpose of communication. The two special types of slots in each frame are the Request (REQ) and the Reply (REP) slots which are separated into mini slots. The mini slots of REQ are used in the uplink and mini slots of REP are utilized in the downlink. The REP mini slots are modified to a matrix of data slots and CDMA codes as in fig1.The data slot and CDMA for a user are assigned by a scheduling algorithm and this data is send to the user as a REP signal by the BS. The protocol allows multiple users to transmit data in multiple slots of a frame using their own CDMA codes.

Adaptive power control

An Adaptive power control algorithm is applied at the beginning of each frame to minimize power .If the observed traffic is high power is increased; if traffic is low power is decreased. The power control mechanism adjusts the transmitted power to maintain the received SIR equal to the SIR target at the receiver. The transmitter will be controlled to increase OR decrease the transmit power, so that received SIR is close to the SIR target.

In the proposed algorithm an Adaptive Control Factor (ACF), is used. The power control step size is adapted by multiplying a factor called Adaptive Factor (AF) with the fixed step size. This factor will be updated according to received" Transmit Power Control" or TPC.

We are introducing another parameter, Power Determining Factor (PDF) based on the data traffic rate, to determine the power. Based on this parameter, we are determining whether the power is increasing or decreasing. Depending on the traffic rate, the PDF factor is updated ie, If the received message is HCM, then it will increase the parameter and subsequently increases the power and if the message is Low contention (LC), then the parameter will be decreased and correspondingly the power also.

The transmit power is updated according to the following equation:

$$P_u(t+1) = P_u(t) + AF_u(t) . PDF_u(t) \lambda . TPC_u(t) \qquad (2)$$

Where AFu (t) is the Adaptive Factor of uth user at time t, and TPCu (t) is the TPC command of uth user at time t, corresponding to sign (SIR target-SIRest) in Equation 2, and PDFu (t) is the Power Determining Factor. If the received message is HCM, then it will increase the parameter and subsequently increases the power and if the message is LC, then the parameter will be decreased and correspondingly the power also.

III. CAPACITY OF WCDMA SYSTEM

To determine the capacity of a WCDMA Network it is essential to understand the capacity of a single WCDMA cell, which is also referred to as the WCDMA cell capacity. It is normally defined as maximum amount of communication traffic in terms of bits or services in terms of number of simultaneous calls or sessions that can be supported by the cell. Let's consider the uplink *SINR* of a single cell CDMA system and suppose there are altogether N users are permitted to access the radio resource without sacrificing the QoS, If Pik is the transmitted power to the mobile 'I' located in cell K . Let hik is the path gain between MSi and base station K. Let the Received signal power is Pr and it is given as Pik x hik

Where P_r is the received signal power. Is the Intra cell interference caused by the other users in the same cell? Is the Inter cell Interference caused by users from outside cells? N is thermal Noise. We assume *N* and are constant during the analysis. In the CDMA system, it is reasonable to assume that the Interference is much larger than the thermal noise, so in the following analysis, we simply ignore Noise. We also ignore Inter cell Interference caused by users from outside cells .So we consider Intra cell interference in our analysis.

Capacity is given as

$$M = G_p \left[\frac{\eta_c}{\frac{Eb}{It} V_f (1+f)}\right]$$

Gp is the processing gain, is Power control accuracy factor, Vf is voice activity factor.

The target Eb/No value plays an important role in determining the WCDMA cell capacity. On the uplink, the high target Eb/No requires high transmission power and high interference and in WCDMA, for each user, the other users' signals are interference.

IV. ADAPTIVE CALL ADMISSION CONTROL ALGORITHM

Let Pt be the total power of the existing users in the network. Let Pa be the total available power. Let Pr be the power of the requested new user to get admission in the network.

1. Wait for new call request arrival.
2. If a new call request arrives.
3. If the call is hand off call.
4. If Pt+ Pr < Pa
5. Admit the request call.

Else
6. If Pt+ Pr >Pa
7. Degrade the existing users who are using Non real time services.
8. After degrading NRT services If Pt+ Pr < Pa
9. Admit the request call.

Else
10. If still Pt+ Pr >Pa
11. Degrade the existing users who are using real time services.
12. After degrading RT services If Pt+ Pr < Pa
13. Admit the request call.

Else
14. If still Pt+ Pr >Pa
15. Reject the requested call.
16. Else if it is new call repeat steps 4 to 15.

V. SIMULATION RESULTS

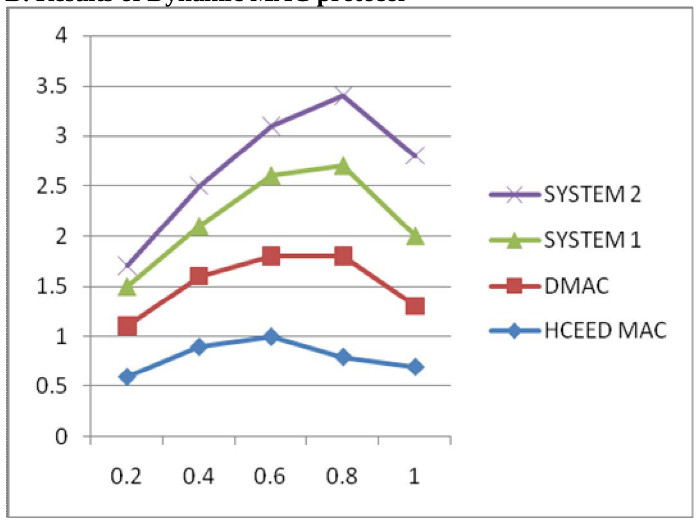
A. Simulation Setup

In this section, we simulate the proposed HCEEDMAC protocol, DMAC protocol, System I (N. Mohan and T..Ravichandran has proposed a new CAC algorithm with power control and adaptive scheduling scheme), System II (Rekha Patil and A. Damodaram with have proposed joint scheduling for admission and power control algorithm) and compare based on capacity and Throughput. 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 region for 50 seconds simulation time. Random waypoint (RWP) model of NS2 is used to obtain the initial locations and movements of the nodes. The transmission range of all nodes is 250 meters. The simulation parameters are given in table I.

Table I. Simulation Parameters

Area Size	600 X 600
Number of Cells	2
Users Per Cell	32
Slot Duration	2 m sec
Radio Range	250m
Frame Length	2 to 8 slots
CDMA codes	2 to 5
Simulation Time	50 sec
Routing Protocol Traffic Source	AODV CBR, VBR
Video Trace	JurassikH263-256k
Packet Size	512 bytes
MSDU	2132
Tx power, Rx power	0.66w,0.395w
Speed of mobile	25m/s

B. Results of Dynamic MAC protocol



As shown in figure 2 as the arrival rate increases throughput increases more in HCEEDMAC when compared to DMAC, system I, system II . Because of Adaptive power control technique the power is efficiently utilized and more number of users are accommodated in HCEEDMAC protocol when compared with DMAC protocol, system I, system II

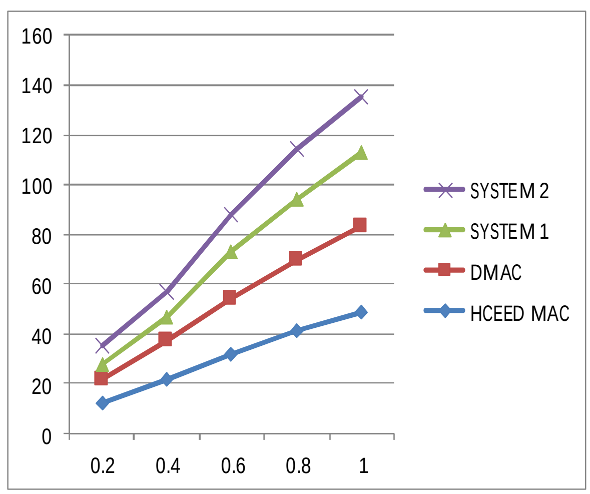


Figure3. Capacity Vs Arrival Rate

Figure 3 shows the capacity with arrival rate for both HCEEDMAC and DMAC. Capacity is getting increased in both HCEEDMAC, system I, system II, DMAC as arrival rate increases. HCEEDMAC uses less energy when compared with DMAC because HCEEDMAC uses adaptive power control technique and energy is efficiently utilized hence number of users are accommodated in HCEEDMAC when compared with DMAC protocol, system I , system II

VI. CONCLUSION

In this paper a High Capacity Energy efficient Dynamic MAC protocol (HCEEDMAC) for wireless multimedia networks is developed by using WCDMA scheduling algorithm, Adaptive Power Control Algorithm (APC), Adaptive Call Admission Control Algorithm(ACA).To reduce power consumption Adaptive Power Control algorithm (APC) is applied to Dynamic MAC protocol. To reduce blocking probability Adaptive Call Admission Control algorithm (ACA) is applied. By simulation, it is shown that proposed Dynamic MAC protocol (DMAC) achieves high throughput under low and high data traffic. Adaptive Power Control (APC) algorithm reduces power consumption of multimedia traffic, hence reduces interference and increase capacity. Adaptive Call Admission Control Algorithm is based on power control reduces the blocking probability and increases the capacity of the system.

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