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A MAC Protocol with CAC algorithm for Wireless Networks

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Abstract— Wireless communications has become ubiquitous these days. With the advent of multimedia applications, there is a need for higher bandwidth and faster data rates. A Medium Access Control (MAC) protocol is required for effective utilization of network resources and to transmit multimedia traffic classes with quality of service requirements. In the proposed Dynamic MAC protocol under low load conditions users can access any slots and in high load conditions the owners of the slots have priority to access slots. If the owners are not having any data to transmit the non-owners can access slots. Adaptive Call Admission Control algorithm for multimedia traffic is used to control congestion, which in turn reduces the blocking probability and hence maximizes system capacity. The performance of the proposed protocol is evaluated based on Throughput, Call blocking probability,Capacity.

Keywords — W-CDMA, MAC protocol, Wireless networks, Call blocking probability, Call Admission control, Adaptive Power Control ,Capacity.

1. INTRODUCTION

Wireless communications is going under explosive growth. Today, there are approximately 5.9 billion mobile subscribers. The development of wireless network technologies has led to different generations of wireless systems named as nG (1G, 2G, 2.5G, 3G, etc). Third generation wireless networks are WCDMA or UMTS-FDD (Universal Mobile Telecommunications System- Frequency Division Duplex), CDMA2000, UMTS–TDD (Time Division Duplex) or TD-SCDMA (Time Division-Synchronous Code Division Multiple Access) and are suitable for multimedia transmission. The current trend in wireless network is to carry multiple multimedia traffic classes for more number of users by allocating resource efficiently and reliably. The system capacity is limited with the growing demand of wireless services and the resources should be used efficiently. A Dynamic Medium Access Control is required for better radio resource utilization and to provide users with quality of service requirements for multiple multimedia traffic classes. Many MAC protocols are proposed for wireless multimedia networks. The basic MAC protocols for CDMA communication systems proposed by Liu and E Zarki [1] are distributed random access MAC protocols. These protocols are *unstable* at higher load conditions. C.Roobol et al [2] have proposed a RLC/MAC protocol. In this protocol different multimedia traffic classes uses different transmission modes and reservation procedures. This proposal does not consider the mechanism of allocating resources to different services. R.Patil and A.Damodaram [3] have proposed cross layered joint call admission and power control algorithm. This proposal does not consider scheduling mechanism for allocating resources to different services. A robust Call Admission Control and power control mechanism are required for the QoS provisioning in wireless network. *A* MAC protocol with efficient packet scheduler is required to be combined with an call admission controller.N. Mohan and T.Ravi chandran [4] have proposed a 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 capacity enhancement by the network. Hence there is an urgent need to develop a High Capacity Energy efficient Dynamic MAC protocol to improve the network capacity using power and admission control. It is most challenging task to improve capacity, to control interference level and to control congestion for different multimedia traffic classes in wireless multimedia networks.

The key idea is to propose a Dynamic MAC (DMAC) protocol with adaptive power control and call admission control algorithms for wireless multimedia networks. MAC protocol can be made dynamic by using contention based scheduling. High capacity and Energy efficiency can be achieved by using power control technique which reduces the interference level and call admission control mechanism which controls the congestion in the network.

The proposed MAC protocol is based on contention and uses multiple slots per frame allowing multiple users to transmit data simultaneously using their own CDMA codes. If there is low contention in the network users can access any slots and if there is high level contention in the network the owners of the slots have priority to access slots. If the owners are not having any data the non owners can access slot according to scheduling algorithm. An adaptive power control algorithm is applied to maximize capacity and to reduce interference. Power will be increased if the observed traffic is high and decreased if traffic is low. To control call admissions in the network, a Adaptive call admission control algorithm is applied which reduces the blocking probability.

The paper is organized as follows: In section II we explain dynamic MAC protocol for wireless multimedia networks. Section III discusses Adaptive call admission control mechanism. In section IV simulation results are discussed. The paper is concluded in section V.

II. DYNAMIC MAC PROTOCOL

A. Scheduling

In Dynamic MAC protocol data traffic may be in two modes i). Low Contention Mode (LCM).ii). High Contention Mode (HCM).For low data traffic conditions the network is said to be in Low Contention mode and under high data traffic conditions the network is said to be in High contention mode. If the data traffic is greater than threshold value DT_{th} then it is in high contention mode or else it is in low contention mode. Base station calculates the data traffic by using the expression

13.In our analysis we assume that M is the maximum number of active users in the cell and if the number of users is less than M/2 then network is said to be in low contention mode otherwise it is in high contention mode. In low contention mode users can transmit data in any slot. In high contention mode the slots are reserved for traffic classes and the users who reserved the slots are called as owners. In high contention mode owners of current slots are allowed to contend for the channel, if an owner does not have data the non owners are allowed to compete the channel according to priority of traffic classes. Traffic classes with highest priority are first allowed to compete the channel. In both low contention and high contention modes Real Time traffic classes are given more priority than Non Real Time traffic classes.

B. Frame Structure.

A frame is divided into N time slots and each frame consists of two special slots the Reply (REP) slots and the Request (REQ) slots which are subdivided into mini slots. The REQ slots are used in the uplink for requesting the slots for data transmission by the users. The REP mini slots are used in the down link indicating slots for data transmission to the users. REP mini slots are divided into grids where grid is equal to maximum number of users that can transmit data in a slot. The data slots are allocated according to the scheduling algorithm and this information is send to the user a REP signal by the Base Station.

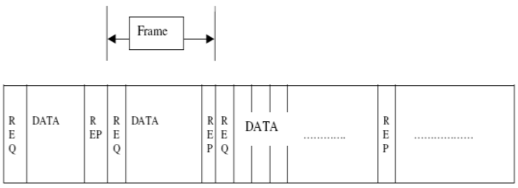

Figure1: MAC frame

Where, REQ –Request slot, REP – Response slot

C. Analytical Model.

We consider a single cell consisting of base station and M active nodes or mobile users transmitting messages to other node through the base station. Two types of links are defined in this model.

i).Uplink: This describes data transmission from Mobile terminal to the Base station.

ii).Downlink: This describes the data transmission from Base station to the Mobile terminal.

For analysis the following assumption are made.

i).Each node or user generates messages according to Poisson distribution with arrival rate λ.

ii).The service rate of each message is exponentially distributed.

iii).The nodes cannot generate new message until all packets of current message are transmitted completely.

iv). If a node or user completed its transmission in current frame, it cannot generate message in the same frame.

The message signal b(t) is multiplied by the spreading code c(t),each information bit is chopped into a number of small time increments commonly called as chips. The transmitted signal m(t), may be expressed as m(t)= c(t).b(t) (1)

The received signal r(t) contains the transmitted signal m(t), noise signal n(t) and the interference signal i(t).

$$r(t) = m(t) + i(t) + n(t) = c(t).\, b(t) + i(t) + n(t) \quad (2)$$

Where, n(t) is Additive White Gaussian Noise (AWGN) in the receiver. The message signal b(t) is recovered from the received signal r(t) by multiplying the received signal r(t) with the transmitted code c(t) At the receiver the demodulated output z(t) is given by

$$z(t) = c(t).\, r(t) = c2(t).b(t) + c(t).\, i(t) + c(t).n(t) \quad (3)$$

Since, $c2(t) = 1$ (the autocorrelation property of the PN code,)

$$z(t) = b(t) + c(t).i(t) + c(t).n(t) \quad (4)$$

For the random access protocol, we use the M/M/n/n/K Markov model by obtaining the steady state equation as:

$$\vec{x}\, A = O \quad (5)$$

Where 'O' is a null matrix and A is the generator matrix, $\vec{x}$ is a steady state probability vector and it is equal to $\vec{x} = \{x_0, x_1, x_2 \cdots x_n\}$

(6)

For this Markov chain, the recurrent non-null and the absorbing properties are satisfied. 'n' is the number of data slots and 'K' is the number of users. The average number of packets served by the system is calculated as:

$$PA = \frac{(K\mathrm{T})\sum_{i=0}^{n-1}\binom{K-1}{i}T^{i}}{\sum_{i=0}^{n}\binom{K}{i}T^{i}} \quad (7)$$

Here, T is the offered traffic to the system with the arrival rate and T is given by;

$$T = \frac{\lambda}{\mu} \quad (8)$$

Where, λ is Poisson distribution and the service rate and μ is the exponential distribution.

The probability of the packet success rate PSR is calculated as;

$$PSR = \sum_{k=0}^{c}\sum_{j=0}^{n}(1 - xj)(1 - Berr(k)) \quad (9)$$

here " c" is the active number of CDMA codes allocated to the active users in a data slot and the steady state probabilities are given as;

$$x0 = \frac{1}{\sum_{i=0}^{n}\binom{K}{i}T^{i}} \quad \text{And} \quad (10)$$

$$xj = \binom{K}{j} T^{j} x0 \qquad (11)$$

and Berr(k) is the BER value, which is given by the relationship as;

$$Berr(k) = \frac{1}{2} erfc\left(\sqrt{\frac{Eb}{No + \frac{2}{3} Eb(\frac{k-1}{\beta p})}}\right) \qquad (12)$$

Where,

k = Number of active user.

βp = Processing gain of the spectrum.

Eb = Energy per bit in joules

No = The two-sided psd in Watts/Hz

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

$$DT = \left[\frac{\beta p}{SIR}\right] \times \frac{1}{1+\kappa} \times P \times \frac{1}{\Phi} \times \beta a \qquad (13)$$

Where, βp and βa = the processing gain by spreading the spectrum and sector antenna gain respectively.

SIR = Signal to interference ratio

κ = The interference from other nodes

P = The power control factor

Φ = The voice/data activity factor.

III. ADAPTIVE CALL ADMISSION CONTROL ALGORITHM.

Let B_t be the total available bandwidth of the existing users in the network. Let B_a be the total available bandwidth. Let B_r be the requested bandwidth of 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 $B_{t+} B_{r<} B_a$
5. Admit the request call.
   Else
6. If $B_{t+} B_{r>} Ba$
7. Degrade the existing users who are using Non real time services.
8. After degrading NRT services If $B_{t+} B_{r<} B_a$
9. Admit the request call.

   Else

10. If still $B_{t+} B_{r>} B_a$
11. Degrade the existing users who are using real time services.
12. After degrading RT services If $B_{t+} B_{r<} B_a$
13. Admit the request call.

    Else

14. If still $B_{t+} B_{r>} B_a$
15. Reject the requested call.
16. Else if it is new call repeat steps 4 to 15.

In the above algorithm priority is given for hand off request calls, since handoffs are important then the new calls. Here non real time services are degraded first when compared with real time a service. The existing users are degraded to a minimum power level till they maintain acceptable quality of service in the network.

IV. SIMULATION RESULTS

A.Simulation Setup

In this section, we simulate the proposed protocol HCEEDMAC for WCDMA cellular networks. 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
Duration of data Slot	1.8 m sec
Duration of RTS Slot	0. 5 m sec
Duration of CTS Slot	0. 5 m sec
Frame duration	10 m sec
CDMA codes	2 to 5
Traffic Source	CBR, VBR
Packet Size	512 bytes
Video Trace	JurassikH263-256k
Tx power	0.66w
Speed of mobile	25m/s
No. of Users	36

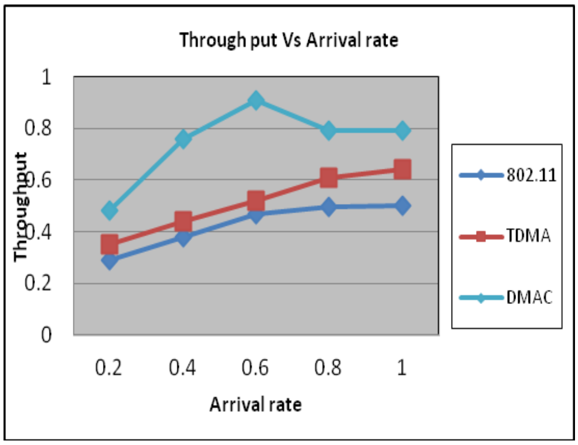

Figure 2 Throughput Vs Arrival Rate

From Figure 2 throughput increases more in DMAC when compared to TDMA and 802.11 MAC as the arrival rate increases. We have considered 2 to 5 CDMA codes per slot. The network is in low contention mode up to 0.5 arrival rate the throughput increases and reaches a maximum value. In low contention mode users can access any slots and all the users obtained slots for transmission and hence maximum throughput is achieved in this mode. The network is in high contention mode, when the arrival rate is more than 0.5 and the throughput slightly decreases and maintains constant. In high contention if the slots are not used by the owners, the other users can access the slots. As 5 users are transmitting data in a slot in DMAC rejection rate is very small so through put is more. Whereas in TDMA, the slots are reserved for users and if the users are not having data to transmit the slots cannot be used by other users, so throughput is less in TDMA when compared to DMAC. 802.11 MAC has lower throughput than DMAC and TDMA.

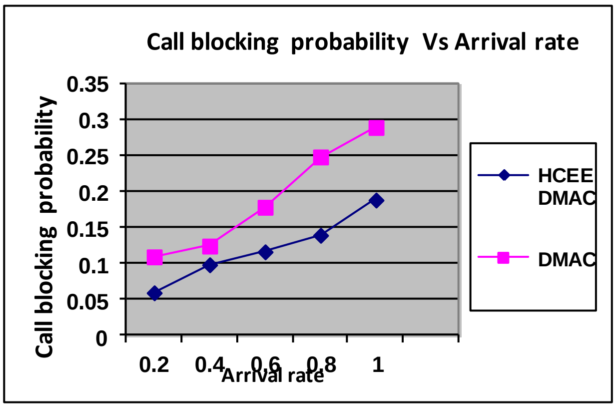

Figure 3. Call blocking probability Vs Arrival Rate

As shown in figure3 the Call blocking probability of DMAC (Dynamic MAC Protocol without Call admission control) is compared with HCEEDMAC (Dynamic MAC protocol with Adaptive Power control and Call admission control algorithm). If there is no sufficient bandwidth for new arriving users in the network, the bandwidth of ongoing connections are degraded according to priority and given to new requesting users or handoff calls. After degrading if there is no sufficient bandwidth the call will be blocked or dropped. HCEEDMAC is based on adaptive Call admission control and resources are efficiently utilised, hence Call blocking probability is less in HCEEDMAC compared with DMAC algorithm.

V. Conclusion.

In this research work a High Capacity Energy efficient Dynamic MAC protocol (HCEEDMAC) for wireless multimedia networks is developed by using scheduling algorithm.Adaptive Call Admission Control Algorithm (ACA). Dynamic MAC (DMAC) protocol is evaluated by varying arrival Rates. DMAC protocol achieves high channel utilization and improved throughput with reduced average delay under low and high data traffic conditions compared with TDMA and 802.11. The scheduling mechanism avoids the stability problem at high loads and also gives priority to real time services and effectively utilizes the channel.

Adaptive Call Admission Control Algorithm (ACA) is evaluated by varying the arrival rate. The ACA algorithm reduces the call blocking probability and maximizes system capacity. HCEEDMAC is based on adaptive Call admission control and resources are efficiently utilised, hence Call blocking probability , Call dropping probability is less in HCEEDMAC compared with DMAC algorithm. In summary by simulation, it is shown that proposed Dynamic MAC protocol (DMAC) achieves high channel utilization and improved throughput with reduced average delay under low and high data traffic. Adaptive Call Admission control algorithm (ACA) is reduces the blocking probability and call dropping probability and increases the capacity of the system.

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