DESIGN OF DYNAMIC MAC PROTOCOL FOR WIRELESS MULTIMEDIA NETWORKS.

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ABSTRACT

A Dynamic MAC protocol is developed for WCDMA wireless multimedia networks. It uses multiple slots per frame allowing multiple users to transmit simultaneously using their own CDMA codes. The proposed MAC protocol is based on contention .If there is low contention users can access any slots and if there is high level contention the owners of the slots have priority to access slots .If the owners are not having any data the non owners can access slots. An adaptive power control algorithm is applied to reduce transmission power, interference level, and to maximize system capacity. If the observed traffic is high, power will be increased; if traffic is low power will be decreased. By simulation results, we show that our proposed MAC protocol achieves 100% throughput under low contention and 90% throughput under high contention and also reduces power consumption.

KEYWORDS

Wideband Code Division Multiple Access (W-CDMA), MAC protocol, Direct Sequence Spread Spectrum (DSSS), Medium Access control, Multimedia networks.

1. INTRODUCTION

Third generation systems (3G) such as Wide band code division Multiple Access are designed for wireless multimedia networks. It provides high quality image and video transmission and support for a wide range of services with higher rates and with increased network capacity. The current trend in wireless network is to provide multiple multimedia traffic class with quality of service for more number of users by allocating resource efficiently and reliably. To improve the radio resource utilization and to provide users with quality of service requirements a Medium Access Control [1] is required. Many MAC protocols are proposed for wireless multimedia networks to maximize the throughput and to transmit multiple multimedia traffic classes with required quality of service. The basic MAC protocols for traditional communication systems are designed for voice communication and are unstable at higher load conditions. Different MAC protocols for wireless multimedia network are proposed for congestion control, Interference control but there is trade off between the performance metrics of proposed protocols. In this paper a Dynamic MAC protocol for wireless multimedia networks is proposed

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and an adaptive power control algorithm is applied at the beginning of each frame to reduce interference. The proposed MAC protocol is based on contention. If there is low contention users can access any slots and if there is high level contention the owners of the slots have priority to access slots. If the owners are not having any data the non owners can access slots. To maximize system capacity and to reduce interference an adaptive power control algorithm is used. If the observed traffic is high power is increased, if traffic is low power is decreased. The paper is organized as follows: In section II existing works on MAC protocols are discussed. In section III Dynamic MAC protocol for wireless multimedia networks is developed. In section IV Adaptive power control mechanism is derived for multimedia traffic in WCDMA networks. The Dynamic MAC protocol is evaluated through simulations in section V. The paper is concluded in section VI.

2. RELATED WORKS.

1. Z.Tang and J.J Garcia have proposed a CATA Protocol [2] based on Contention and reservation protocols. Each slot is sub divided into five mini slots. The first four mini slots are control ones labeled as CMS1, CMS2, CMS3, and CMS4 and are used to secure and reserve time slots and the last slot labeled DMS used for transmission of data packets. It is more flexible in terms of bandwidth management when compared with allocation protocols. In this protocol more slots are used for secure and reservation and it is unstable for certain traffic loads and mobility rates.

2. Lixin Wang and Mounir Hamdi have proposed a Hybrid adaptive MAC protocol (HAMAC) [3] based on TDMA, reservation, and contention protocols. It allow the contention channel to transmit data, unlike many other proposals in which the contention channel is used only for reservation and control signaling. It can efficiently adapt to the traffic the variance in CBR, VBR, and ABR traffic due to the mobility of mobile devices. The protocol uses isochronous service features of time division multiple access protocol and a new preservation slot technique to reduce packet contention overhead for voice and CBR traffic. In this protocol low delay is achieved for light traffic load.

3. I. Chlamtac, and A. Farago have proposed a ADAPT protocol [4] based on channel allocation TDMA protocol and contention protocol .Each mobile terminal is assigned a slot in a frame considering as owner. In each slot their is sensing interval in which only the slot owner may contend for the channel by initiating hand shake and the other users (non owner) cannot transmit data.

4. Zhijun Wang, Umapathi Mani, and MiaoJu, Hao che have proposed a RAH-MAC [5] protocol based on combination of polling and contention MAC protocols .Data transmission rate is dynamically adjusted based on the channel condition and it uses variable transmission rate. More priority is given to voice traffic but not for other traffic.

5. Ian F. Akyildiz has proposed a WISPER protocol [6] based on TDMA and CDMA .Slots are filled according to the BER requirements. Here the protocol is simple to implement in that only one power level can be used for each slot rather than several power levels depending on the number of traffic classes when congestion occurs, voice packets are the first to be sacrificed.

6. C. Roobol et al have proposed a RLC/MAC protocol [7].In this protocol slots are filled according to load, traffic class and transmission rate .The BER of traffic classes are controlled using Power control algorithm .Different transmission formats specified for transmission.

7. A.Saravan, B.parthasarathy has proposed an Analytical Model MAC Multi protocol [8] based on OFDMA, TDMA and CDMA systems. The reservation and polling methods of MAC protocols are used to handle both low and high data traffics of the mobile users. In this protocol frame is divided into different slots and the slots are transmitted with users CDMA codes.

8. Rekha Patil and A. Damodaram [9] with objective of reducing call rejection rate and to minimise interference have proposed joint scheduling and power control algorithm. The algorithm is based on optimum number of users with optimum transmitting power level. The set of optimum power levels that could be used by the users for successful transmission are determined and are solved the problems in distributed power control algorithm.

9. Rachod Patachaianand, Kumbesan Sandrasegaran [10] has proposed a new adaptive power control algorithm by eliminating limitations in current power control algorithms for UMTS. When channel fading changes slowly the proposed algorithm reduces SIR variations and capable of tracking quick changes in fast fading channels where other power control algorithms to handle.

10. Rachod Patachaian and Kumbesan Sandrasegaran [11] have proposed a new adaptive power control algorithm. The algorithm uses Consecutive TPC Ratio (CTR) to adjust power control step sizes. They showed that there is correlation between user mobility and TPC sequences.

EXISTING WORKS ON MAC PROTOCOLS				
Sl.No	**Algorithm**	**Principle / slots assignment**	**Advantages**	**Disadvantages**
1.	CATA PROTOCOL	Contention and reservation protocols	More flexible in terms of bandwidth management when compared with allocation protocols	1. More slots are used for secure and reservation. 2. Un stable for certain traffic loads and mobility rates.
2.	HAMAC PROTOCOL	1.TDMA, reservation, and contention protocols 2. The protocol uses isochronous service features of time division multiple access protocol and a new preservation slot technique to reduce packet contention overhead for voice and CBR traffic.	1. Results in very low delay in case of light traffic load. 2.Dynamic bandwidth allocation strategy 3.Eliminates the reservation overhead of CBR traffic, which results in less contention	RAH-MAC is superior than HAMAC

3.	ADAPT PROTOCOL	TDMA protocol and contention protocol	Dynamically manages the band width	Only slot owners can transmit data in their slot others cannot use it and channel is not efficiently utilized
4.	WISPER protocol	1. Based on TDMA and CDMA 2. Slots are filled according to the BER requirements. 3. WISPER is a reservation-based protocol.	protocol is simple to implement in that only one power level can be used for each slot rather than several power levels depending on the number of traffic classes	When congestion occurs, voice packets are the first to be sacrificed.
5.	RAH-MAC	Combination of polling and contention MAC protocols	Data transmission rate is dynamically adjusted based on the channel condition and it uses variable transmission rate	More priority is given to voice traffic but not for other traffic.
6.	RLC/MAC	According to load, traffic class and rate	BER of traffic classes are controlled using Power control algorithm	Different transmission formats specified for transmission
7.	Analytical Model MAC Multi protocol.	OFDMA,TDMA and CDMA systems	Capacity of system increased	Results in delay for certain traffic
Existing Works on Power control				
8.	cross-layer based joint scheduling and power control algorithm	determines the optimum set of admissible users with suitable transmitting power level	solved the multiple access problems in the distributed power control algorithm	The power control is not adaptive.
9.	Adaptive step size power control with TPC command	The algorithm uses Consecutive TPC Ratio (CTR) to adjust power control step sizes. There is correlation between user mobility and TPC sequences.	capable for tracking the rapid changes of multipath fading by utilizing existing TPC commands	The power control is not based on the data traffic classes

10.	New Adaptive step size power control for UMTS	When channel fading changes slowly the proposed algorithm reduces SIR variations and capable of tracking quick changes in fast fading channels where other power control algorithms to handle .	Eliminates the drawbacks of conventional power control	The power control is not based on the data traffic classes

3. DYNAMIC MAC PROTOCOL

3.1 DS-SS (CDMA) Based MAC Scheme

By multiplying the message signal b(t) by the spreading code c(t),each information bit is chopped into a number of small time increments commonly called as chips. Thus transmitted signal m(t), may be expressed as: m(t)= c(t). b(t) (1)
Which is a wideband signal. The received signal r(t) contains the transmitted signal m(t),noise n(t) and the interference i(t). The interference signal contains Intra cell Interference and Inter cell interference $r(t) = m(t) + i(t) + n(t) = c(t).\ b(t) + i(t) + n(t)$ (2)

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

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

3.2WCDMA Scheduling

In Dynamic MAC protocol data traffic is calculated at each node and the node may be in low contention mode or in high contention mode. If the data traffic at a node is greater than threshold value DT_{th} then the node is said to be in high contention mode otherwise the node is said to be in low contention mode. In low contention mode any node can transmit data in any slot .In high contention mode the slots are reserved for certain 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 owner does not have data the non owners are allowed to compete the channel according to priority of traffic classes. In both cases real time traffic is given more priority than non real time traffic.

FRAME									
R E Q	DATA	R E P	R E Q	DATA	R E P	R E Q	DATA	…………..	R E P

Where, REQ- Request, REP-Response

Fig1: MAC frame

The time is divided into fixed size frames in the proposed protocol. A frame has N time slots and two special slots the Request (REQ) and the Reply (REP) slots which are separated into mini slots. The mini slots of REQ are used in the uplink for transmission request by the users and mini slots of REP are utilized in the downlink. The REP mini slots are modified to a matrix of CDMA codes and data slots 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 Base Station (BS).

A REQ signal along with some control information's is send to BS by the user which is ready for transmission. The scheduling algorithm of BS enables the user to get a REP signal about the data slots and CDMA codes. Enabling the user to transmit the data together with the processing of the requests of the nodes and the scheduling is done with the help of the REP signal. In our dynamic work, each terminal transmits at the time slots during which it is allowed to transmit using its own code sequences.

The REP is divided into mini slots, each holding information of the corresponding data slot in the next frame. Each mini slot is further divided into grid, where grid is equal to the maximum number of nodes that can transmit data simultaneously in a data slot. Each of these grids is initialized with a code which the scheduler allocates to the node which succeeded in getting a reservation for that slot.

3.3. Analytical Model.

While describing the access system we take only one mobile cell into account in which there are M active nodes(or users) that generates messages to be transmitted to another node where the base station controls all the nodes within the cell. Two kinds of links are possible in this model.

1. Uplink: this demonstrates data transmission from mobile station MS to BS.
2. Downlink: this describes the data transmission from BS to MS.

For the analysis following assumptions are made.

1. Each node generates messages which is Poisson distributed with arrival rate λ.
2. The message length of each node is exponentially distributed.
3. The nodes cannot generate new message until all packets of current message are transmitted completely.
4. If a node completes its transmission in current frame, it cannot generate message in the same frame.
5. Let the maximum number of users that can be accommodated in the cell is N.

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 A is the generator matrix, 'O' is a null matrix and $\vec{x}$ 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;

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

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

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

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

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.

4. Dynamic MAC Protocol with Power Control.

The adaptive power control algorithm uses TPC commands and power determining factor. Adaptive factor is calculated based on TPC commands. Power determining factor is calculated based on traffic rate.

4.1Adaptive Step Size Estimation

The power control step size is modified by multiplying a factor called Adaptive Factor (AF) with the fixed step size. The algorithm uses transmission power control commands (TPC) to calculate Adaptive factor based on predefined adaptive control factor which is defined by the network. Based on the received two most recent TPC commands the adaptive factor is updated.TPC command increases or decreases the transmitting power. If same TPC commands are detected the step size will be increased or else the step size will be decreased. Power Determining Factor (PDF) is computed based on the data traffic rate to determine whether the power is decreasing or increasing. PDF factor is updated according to the traffic rate

The transmit power can be represented as:

$$P(t+1) = P(t) + \lambda .\ \text{sign}(SIR_{target} - SIRest)\ [dB] \qquad (14)$$

Where SIR_{est} and SIR_{target} are the estimated and target SIR respectively, λ is the power control step size and P (t) is transmit power at time‘t’. The term sign is the sign function: sign(x) = 1, when $x \geq 0$, and sign(x) = -1, when $x < 0$.

The transmit power is updated according to the following equation:

$$Pu(t+1) = P\,u(t) + AFu(t).\ PDFu(t)\ \lambda .\ TPC\ u(t) \qquad (15)$$

PDFu (t) is the Power Determining Factor, TPCu (t) is the TPC command of u^{th} user at time t, related to sign (SIR_{target}-SIR_{est}), and AFu (t) is the Adaptive Factor of u^{th} user at time ‘t’.

5. Simulation Results

5.1 Simulation Setup

In this section, we simulate the Dynamic MAC protocol with power control for WCDMA cellular networks. The simulation tool used is Network simulator2. 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 movements and locations of the nodes. All nodes have the same transmission range of 250 meters. In our simulation channel capacity is set to 2 Mbps. The number of users simultaneously transmits data in a slot using CDMA codes is 2 to 5.The simulation parameters are given in table 1.

Area Size	600 X 600
Number of Cells	2
Slot Duration	2 msec
Radio Range	250meters
Frame Length	2 to 8 slots
CDMA codes	2 to 5
Simulation Time	50 sec
Traffic Source	CBR, VBR
Packet Size	512 bytes
Video Trace	JurassikH263-256k
Tx power, Rx power	0.66w,0.395w
Speed of mobile	25m/s
No. of users	32

Table I. Simulation Parameters

5.2. Performance Metric

The performance is mainly evaluated according to the following metrics:

Channel Utilization: It is the ratio of utilised bandwidth to total bandwidth for a traffic flow.

Throughput: It is the successful transmission of packets in a unit of time.

Average End-to-End Delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Energy: It is the average energy utilized by all nodes in transmitting, receiving and forward operations.

5.3. Results of Dynamic MAC protocol

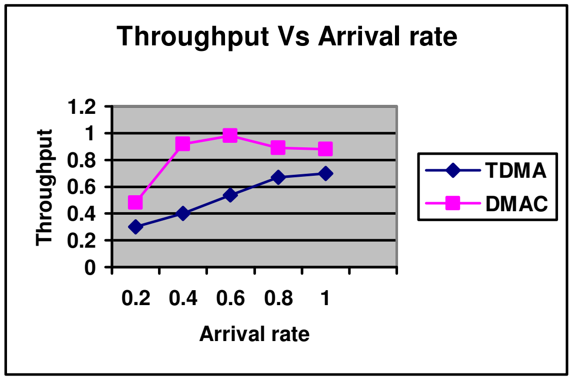

Fig 2. Throughput Vs Arrival Rate

As shown in figure 2 as the arrival rate increases throughput increases more in DMAC when compared to TDMA. 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 of unity. 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 is 0.9 and is 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.

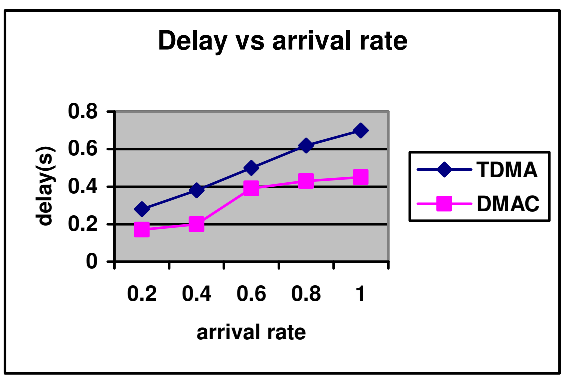

Fig3. Delay Vs Arrival Rate

Fig.3 shows the delay occurred for various rates. It can be observed that the delay increases gradually with increasing arrival. The delay is more for more number of users when the traffic is high .It shows that the delay of DMAC is significantly less than TDMA protocol. In DMAC more users can transmit data in a slot whereas in TDMA one user is allowed to transmit data in each slot .So delay is less in DMAC when compared to TDMA.

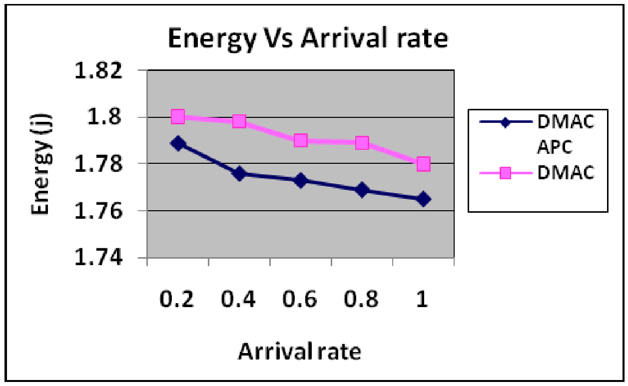

Fig4: Energy Vs arrival rate

Figure 4 shows the energy utilization with arrival rate for both DMAC-APC and DMAC. Energy utilisation is getting decreased in both DMAC-APC and DMAC as arrival rate increases. DMAC-APC uses less energy when compared with DMAC because DMAC-APC uses adaptive power control technique the transmitted power is lowered for low data traffic and power is increased for the high data traffic and hence energy is efficiently utilised. As the users transmit data without adaptive power control more energy is utilised in DMAC protocol than DMAC-APC.

6. CONCLUSION.

In this paper, we have developed a Dynamic MAC protocol for wireless multimedia networks. The proposed MAC protocol is based on contention .If there is low contention users can access any slots and if there is high level contention the owners of the slots have priority to access slot. An adaptive power control algorithm is applied on the protocol. By simulation results, we have shown that our proposed MAC protocol achieves improved throughput with reduced average delay and reduces power consumption of low and high multimedia traffic. Hence the designed protocol will well suit for multimedia data transmission on wireless multimedia network.

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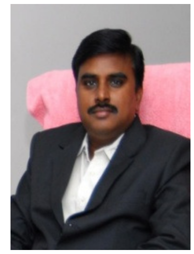

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