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Adaptive Resource Allocation For MAI Minimization In Wireless Adhoc Network

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ABSTRACT

Coding-based solutions for MANETs have emerged as a basic solution to current high rate data accessing in adhoc network. This has become essential related to the absence of centralized control such as a monitoring station. A code assignment protocol is needed to assign distinct codes to different terminals. This problem is less effective in small networks, but becomes dominative in large networks where the numbers of code sequence are lesser than the number of terminals to code, demanding reuse of the codes. The issue of code allocation in communication is focused in this paper with the evaluation of MAI in wireless network. Unlike previously proposed protocols in this paper a focus for the multiple access interference (MAI), thereby addressing the limiting near-far problem that decreases the throughput performance in MANETs is made. The code assignment scheme is developed for the proper usage of users code under MANETs communication to minimize the MAI impact.

Keyword: **adaptive resource allocation, MAI minimization, information sharing, adhoc network.**

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I. INTRODUCTION

Wireless communication standard are now emerging for the service compatibility of demanded services for coming generation wireless communication. The current wireless architecture could be failing in providing the service compatibility in next generations communication standard and need to be improved or merged with other wireless communication standard for this demand compatibility. One such evolving wireless communication technique is mobile Ad Hoc network. Mobile ad hoc networks (MANETs) have recently been the topic of extensive research. The interest in such networks stems from their ability to provide a temporary wireless networking capability in scenarios where fixed infrastructures are lacking and are expensive or infeasible to deploy (e.g., disaster relief efforts, battlefields, etc.). For the integration of coding scheme with adhoc architecture various proposal were made in past. In [1] the addresses part of the packet are spread using the common code, while the rest of the packet is spread using the transmitter-based approach. A receiver notes the address of the source terminal and uses this address to switch to the corresponding code. In [2] the authors proposed the coded tone sense protocol, in which K busy tones are associated with K spreading codes. During packet reception on a certain code, the receiving station broadcasts the corresponding busy tone. In [3] all terminals send the RTS-CTS packets on a common code, while the data packets are sent using a transmitter- or a receiver-based approach. Somewhat similar approaches were proposed in [4] and [5]. In all the above protocols, the authors assume perfect orthogonality between spreading codes, i.e., they ignore the near-far problem. A reservation-based scheme was proposed in [6], whereby small control packets are used to request slot assignments for data packets. The authors investigated the use of FHSS to avoid MAI. Their approach, however, cannot be used for DSSS, which is the method of choice in recent wireless standards (e.g. IS-95). In [7] the authors proposed distributed channel assignment algorithms for SS Multihop networks. Those protocols, however, do not allow for any MAI, and hence cannot support concurrent transmissions of signals with different codes. Clustering as proposed in [7] is another interesting approach for power control in coded networks. It simplifies the forwarding function for most terminals, but at the expense of reducing network utilization (since all communications have to go through the cluster heads). This can also lead to the creation of bottlenecks. In [7] the authors proposed the use of a multi-user detection circuit at the receiver to mitigate the near-far problem in MANETs. The proposed scheme also requires the use of GPS receivers to provide accurate position and timing information. Such a scheme relies heavily on physical layer techniques to mitigate MAI, and makes no effort to account for MAI at the access layer. Moreover, although it is feasible to deploy multi-user GPS receivers at the base station, presently it is impractical (and expensive) to implement such receivers within the mobile terminal. Recently, an interesting approach for joint scheduling and power control in ad hoc networks was proposed [1]. This approach, however, requires a central controller for executing the scheduling algorithm, i.e., it is not a truly distributed solution. Furthermore, it assumes the existence of a separate feedback channel that enables receivers to send their SNR measurements to their respective transmitters in a contention free manner. To achieve a integration of coding scheme over adhoc network to reduce the MAI effect is focused in this paper.

Several coding-based access protocols for MANETs have been proposed in past. These protocols, in general, are based on random channel access, whereby a terminal with a packet to transmit can proceed immediately with its transmission, irrespective of the state of the channel. We refer to such schemes as random access coding. Under appropriate code assignment and spreading-code schemes, the coding protocols are guaranteed to be free of primary collisions. However, the nonzero cross-correlations between different coding codes can induce multi-access interference (MAI), resulting in secondary collisions at a receiver (collisions between two or more transmissions that use different coding codes). This problem is known as the near-far problem. The near-far problem can cause a significant reduction in network throughput, and is to be overcome for designing coding-based access protocols for MANETs. As stated the near far effect in coding based MANET network can cause significant degradation in throughput in wireless network, a methodology for minimizing this MAI is been focused for improving the performance of Mobile Adhoc network. This paper present a methodology for the minimization of MAI in proposed coding based MANET for efficient performance in Mobile Adhoc network. A dynamic power allocation method is been proposed for the minimization of MAI effects in such a network.

II. ACCESS INTERFERNCE PROBLEM

In the uplink of a cellular CODING system, the near-far problem is combated through a combination of open- and closed-loop power control, which ensures that each mobile terminal generates the same signal power at the base station. The base station monitors the received signal power from each terminal and instructs faraway terminals to increase their signal powers and close by terminals to decrease theirs. Unfortunately, the same solution cannot be used in MANETs. To see why, consider the situation in Figure 1. Let d_{ij} denote the distance between nodes i and j. suppose that A wants to communicate with B using a given code and C wants to communicate with D using a different code. Suppose that $d_{AB} \approx d_{CD}$, d_{CB} _ d_{AB}, and d_{AD} _ d_{CD}. Then, the MAI caused by C makes it impossible for B to receive A's transmission. Similarly, the MAI caused by A makes it impossible for D to receive C's transmission. It is important to note that the two transmissions cannot take place simultaneously, irrespective of what transmission powers are selected (e.g., if A increases its power to combat the MAI at B, then this increased power will destroy the reception at D).

Figure 1: Example that demonstrates that power control alone is not enough to combat the near-far problem in MANETs.

The above example reveals two issues. First, it may not be possible for two transmissions that use two different spreading codes to occur simultaneously. Obviously, this is a medium access problem. Second, the two transmission can occur simultaneously if the terminals adjust their signal powers so that the interference caused by one transmission is not large enough to destroy packet reception at other terminals. Obviously, this is a power control problem. So the solution to the near-far problem has to have both elements: power control and medium access.

It is important here to differentiate between the spreading code protocol and the access protocol. The former decides which code is used to spread the signal, but does not solve the contention on the medium. On the other hand, the access protocol is responsible for minimizing or eliminating collisions, thereby, achieving good utilization of the available bandwidth. The use of the access protocol implies that even if a terminal has an available spreading code, it may not be allowed to transmit. The design of our access protocol, described in detail in subsequent sections, is guided by the following objectives:

- The protocol must be asynchronous, distributed, and scalable for large networks. It must also involve minimal exchange of information and must be suitable for real-time implementation.
- The receiver circuitry should not be overly complex in the sense that it should not be required to monitor the whole code set.
- The protocol should adapt to channel changes and mobility patterns.

- Finally, although we assume that a code assignment protocol is running at a higher layer, the access protocol must minimize (or eliminate) collisions even if the code assignment is not "correct". This is important because it is usually difficult to guarantee correct code assignment at all times when network topology is continuously changing.

The access interference problem in a wireless adhoc network is as outlined; Consider the reception of a packet at terminal i. Let $P^{(i)}_0$ be the average received power of the desired signal at the i^{th} terminal. Suppose that there are K interfering transmissions with received powers P_j, j = 1, . . . , K. The quality of the intended reception is adequately measured by the effective bit energy-to-noise spectral density ratio at the detector, denoted by $\mu^{(i)}$. For an asynchronous direct sequence BPSK system, $\mu^{(i)}$ is given by:

$$\mu^{(i)} \triangleq \frac{E_b}{N_{0\text{eff}}} = \left(\frac{2\sum_{j=1}^{K} P_j}{3W P_0^{(i)}} + \frac{1}{\mu_0} \right)^{-1}$$

where W is the processing gain and μ_0 is the $E_b/N_{0\text{eff}}$ ratio at the detector in the absence of interference. As the interfering power increases, $\mu^{(i)}$ decreases, and the bit error probability increases. As an example, consider a coding system that uses BPSK modulation and a convolution code with rate 1/2, constraint length 7, and soft decision Viterbi decoding. Let W = 100. To achieve a bit error probability of 10−6, the required $E_b/N_{0\text{eff}}$ is 5.0 dB. Ignoring the thermal noise and using above equation, the total interference power must satisfy:

$$\frac{\sum_{j=1}^{K} P_j}{P_0^{(i)}} < 47.43$$

Transmitters are, in general, situated at different distances from the receiver. Suppose that the transmission powers are fixed and equal. Consider the case of one interferer (K = 1) at distance d_1 from the receiver. Let d_0 be the distance between the receiver and the intended transmitter. Using the two-ray propagation model for terrestrial communications (power loss $\approx 1/d_4$), it is easy to show that to satisfy the required bit error rate, we must have $d_1 \approx 0.38d_0$. So if there is only one interferer that is at distance less than $0.38d_0$ from the receiver, reliable communication will not be possible (i.e., a secondary collision will occur). The above example shows that the near-far problem can severely affect packet reception, and consequently, network throughput. A good measure of network throughput is given by the expected forward progress (EFP) per transmission, defined as the product of the local throughput of a terminal and the distance between the transmitter and the receiver. The EFP was derived for multihop networks, assuming a slotted system and Poisson distributed terminals in the 2D space. Let p be the probability that a terminal is transmitting a packet in a given time slot (i.e., the per-node load) and let L be the number of nodes that are within a circle centered at the transmitter and of radius that equals the transmitter-receiver separation distance. This paper is to design a coding-based access protocol that prevents this rapid degradation in network throughput.

III. CONTROLLED ACCESS CODING

The operational description of the proposed architecture called "controlled Access coding" (CAC) for MANET is as presented. The controlled Access coding protocol is contention based and uses a modified RTS-CTS reservation mechanism. RTS and CTS packets are transmitted over the control channel (on the common code) at a fixed (maximum) power P_{max}. All potentially interfering nodes, as in the IEEE 802.11 scheme, receive these packets. However, in contrast to the IEEE 802.11 scheme and coding protocols, interfering nodes may be allowed to transmit concurrently, depending on some criteria .For the ensuring data packet, the receiver and the transmitter must agree on two Parameters: the spreading code and the transmission power. Code selection can be done according to any code assignment scheme. The choice of the power level is critical and represents a tradeoff between link quality and MAI. More specifically, as the transmission power increases, the bit error rate at the intended receiver decreases (i.e., link quality improves), but the MAI added to other ongoing receptions increases (i.e., the quality of these receptions deteriorates). In addition to accounting for these two factors, this protocol incorporates an interference margin in the power computations. This margin allows terminals at some interfering distance from the intended receiver to start new transmissions in the future. In this design, two frequency channels were used, one for data and one for control (i.e., FDMA-like partitioning). All nodes use a common spreading code over the control channel, while several terminal-specific codes can be used over the data channel. The different codes used over the data channel are not perfectly orthogonal. However, because of the frequency separation, a signal over the control channel is completely orthogonal to any signal (or code) over the data channel. The splitting of the available bandwidth into two non-overlapping frequency bands is fundamentally needed to allow a terminal to transmit and receive simultaneously over the control and data channels, irrespective of the signal power. This approach is merged with coding architecture for power allocation in MANET nodes for minimum MAI and efficiency improvement during unintended transmissions add nonzero MAI during the dispreading at a receiver. The near-far problem is a severe consequence of MAI, whereby a receiver who is trying to detect the signal of the i^{th} transmitter may be much closer in distance to, say, the j^{th} transmitter than the i^{th} transmitter. When all transmission powers are equal, the signal from the j^{th} transmitter will arrive at the receiver in question with a sufficiently larger power than that of the i^{th} transmitter, causing incorrect decoding of the i^{th} transmission (i.e., a secondary collision). An interference margin is needed to allow terminals at some distance from a receiver to start new transmissions in the future. This margin computation is explained below. Consider an arbitrary receiver i. Let μ^* be the Eb/N0 $_{eff}$ ratio that is needed to achieve the target bit error rate at that receiver. It follows from that to achieve the target error rate, we must have

$$\frac{P_0^{(i)}}{P_{thermal}+P_{\text{MAI}}^{(i)}} \geq \mu^*$$

where $P_{thermal}$ is the thermal noise power and P(i) $_{MAI}$ is the total MAI at receiver I, so the minimum required received power is (P(i) 0)min = μ*($P_{thermal}$ + P(i)*MAI). The interference margin strongly depends on the network load, which itself can be conveyed in terms of the so-called noise rise (ξ(i)), defined as follows:

$$\xi^{(i)} \overset{\text{def}}{=} \frac{\left(\frac{E_b}{N_0}\right)_{\text{unloaded}}}{\left(\frac{E_b}{N_0}\right)_{\text{loaded}}} = \frac{P_{thermal}+P_{\text{MAI}}^{(i)}}{P_{thermal}}$$

Note that ($P^{(i)}$ 0)min = $\xi^{(i)}\mu^*$ $P_{thermal}$ is also dependent on the noise rise. While more capacity can be achieved by increasing the noise rise i.e., allowing larger $P^{(i)}$, the maximum allowable noise rise is constrained by two factors. Given this maximum transmission power, as the noise rise is increased, the received power ($P^{(i)}$0)min must increase (μ* and $P_{thermal}$ are constants) and hence, the maximum range (or coverage) for reliable communication will decrease. Second, increasing the noise rise increases the power used to transmit the packet, which in turn increases energy consumption. Energy is a scarce resource in MANETs, so it is undesirable to trade off energy for throughput. We set the interference margin used by a transmitter to the maximum planned noise rise (ξ_{max}), which is obtained by taking into account the above two restrictions on $\xi^{(i)}$.

The admission scheme allows only transmissions that cause neither primary nor secondary collisions to proceed concurrently. RTS and CTS packets are used to provide three functions. The format of the RTS packet is similar to that of the IEEE 802.11, except for an additional two-byte field that contains the P(j) map value. The format of the RTS packet is as shown in figure 2.

Figure 2: Format of the RTS packet in the CAC protocol.

These packets allow nodes to estimate the channel gains between transmitter-receiver pairs. Second, a receiver i uses the CTS packet to notify its neighbors of the additional noise power (denoted by $P^{(i)}$ noise) that each of the neighbors can add to terminal i without impacting I's current reception. These neighbors constitute the set of potentially interfering terminals. Finally, each terminal keeps listening to the control channel regardless of the signal destination in order to keep track of the average number of active users in their neighborhoods.

The process of packet transfer over the network is explained as follow. If a terminal j has a packet to transmit, it sends a RTS packet over the control channel at Pmax, and includes in this packet the maximum allowable power level ($P^{(j)}_{map}$) that terminal j can use that will not disturb any ongoing reception in j's neighborhood. Upon receiving the RTS packet, the intended receiver, say terminal i, uses the predetermined P_{max} value and the power of the received signal P (ji) received to estimate the channel gain G_{ji}=$P^{(ji)}$ received/P_{max} between terminals i and j at that time. Terminal i will be able to correctly decode the data packet if transmitted at a power $P^{(ji)}$ min given by:

$$P_{\text{min}}^{(ji)} = \frac{\mu^*\left(P_{thermal}+P_{\text{MAI-current}}^{(i)}\right)}{G_{ji}}$$

where $P^{(i)}$ MAI-current is the effective current MAI from all already ongoing transmissions. Note that because of the assumed stationary in the channel gain over small time intervals, G_{ji} is approximately constant throughout the transmissions of the control packet and the ensuing data packet. Now, $P^{(ji)}_{min}$ is the minimum power that terminal j must use for data transmission in order for terminal i to correctly decode the data packet at the current level of interference. This $P^{(ji)}_{min}$, however, does not allow for any interference tolerance at terminal i, and thus all neighbors of terminal i will have to defer their transmissions during terminal i's ongoing reception (i.e., no simultaneous transmissions can take place in the neighborhood of i). The power that terminal j is allowed to use to send to i is given by:

$$P_{\text{allowed}}^{(ji)} = \frac{\xi_{max}\mu^* P_{thermal}}{G_{ji}}$$

If $P^{(ji)}$ allowed < $P^{(ji)}_{min}$, then the MAI in the vicinity of terminal i is greater than the one allowed by the link budget. In this case, i responds with a negative CTS, informing j that it cannot proceed with its transmission. This is to prevent transmissions from taking place over links that provides high MAI. This consequently increases the number of active links in the network (subject to the available power constraints). On the other hand, if $P^{(ji)}_{allowed}$ > $P^{(ji)}_{min}$, then it is possible for terminal i to receive j's signal but only if $P^{(ji)}$ allowed is less than $P^{(j)}$ map (included in the RTS). This last condition is necessary so that transmitter j does not disturb any of the ongoing transmissions in its vicinity. In this case, terminal 'i' calculates the interference power tolerance $P^{(i)}$ MAI-future that it can endure from future unintended transmitters. This power is given by

$$P^{(i)}_{\text{MAI-future}} = \frac{3W\,G_{ji}}{2\,\mu^*}\left(P^{(ji)}_{\text{allowed}} - P^{(i,j)}_{\text{min}}\right)$$

the factor 3W/2 comes from the spreading gain. The next step is to equitably distribute this power tolerance among future potentially interfering users in the vicinity of i. The rational behind this distribution is to prevent one neighbor from consuming the entire $P^{(i)}$ MAI-future.

The distribution of this power tolerance is given as;
If terminal i keeps track of the number of simultaneous transmissions in its neighborhood, donated by K(i) inst. Monitored by the RTS/CTS exchanges over the control channel. In addition, i keeps an average $K^{(i)}{}_{\text{avg}}$ of $K^{(i)}{}_{\text{inst}}$ over a specified window. Then, $K^{(i)}$ is calculated as:

$$K^{(i)} = \begin{cases} \beta(K^{(i)}_{\text{avg}} - K^{(i)}_{\text{inst}}), & \text{if } K^{(i)}_{\text{avg}} > K^{(i)}_{\text{inst}} \\ \beta, & \text{otherwise} \end{cases}$$

where β > 1 is a safety margin.
While communication it is observed that when the within interference is more than the neighbor interference the level of effect observed is high to reduce this interference effect the neighbor interference is to be reduced. On the calculation if the average interference level per node the CTS packets are generated with the available interference margin with the required power transmission request to the neighboring node as shown in figure 3.

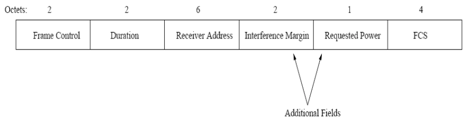


Figure 3: Format of the CTS packet in the proposed protocol.

This demanded power Derived from the CTS packet is then compared with the available power limit and transmitted back for acceptance over the control channel to forward the packet. In case the requested power is more than the limiting power the request is denied. The proposed coding scheme is evaluated over a randomly distributed wireless adhoc network and the obtained result observations are as outlined below.

IV. RESULT OBSERVATION

A randomly scattered wireless network is been considered and the simulation with protocol and without the coding scheme under different topologies conditions. The obtained simulations are as shown below,

The Simulation is performed for;
Structure Network in Delta Topology
Number of Nodes: 10,
Offered simultaneous load : 5

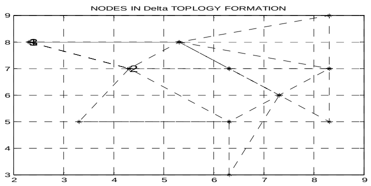


Figure 4: generated Scattered Network

Figure illustrates a generated randomly scattered network with nodes placed on a random location. The nodes are such scattered that each node has connectivity to its neighbor in a delta topology.

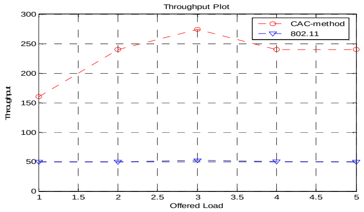


Figure 5: Throughput plot over variable offered load.

Obtained throughput for the developed system for the proposed method and the conventional IEEE802.11 standard. The observation illustrate that as the interference margin is already shared between the nodes on which the communication is to be carried out, the obtained throughput is comparatively higher than the conventional system.

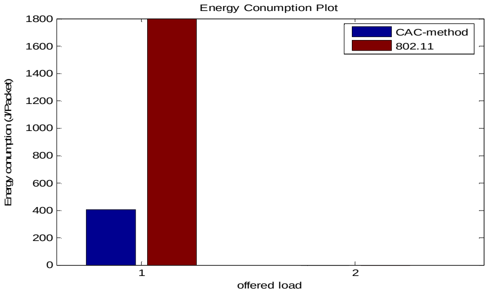


Figure 6: Energy Consumption plot.

The energy consumed per packet transmission and reception is shown in figure above. A comparatively reduction in the total energy consumption is evaluated over different offered data load. It is observed in reduction of total consumed energy reduction due to the priorie knowledge of the interference power available in the channel, which helps in reducing the total packet generation based on the channel condition.

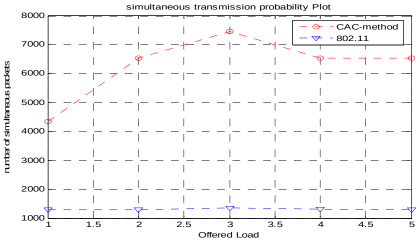


Figure 7 : Simultaneous transmission probability

The simultaneous data transfer probability due to this effect is studied for the two methods wrt. the offered load. With the increase in the offered load it is observed that the probability of transmission of simultaneous packets in the channel get increased as compared to the conventional method.

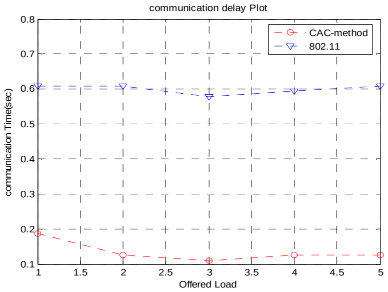
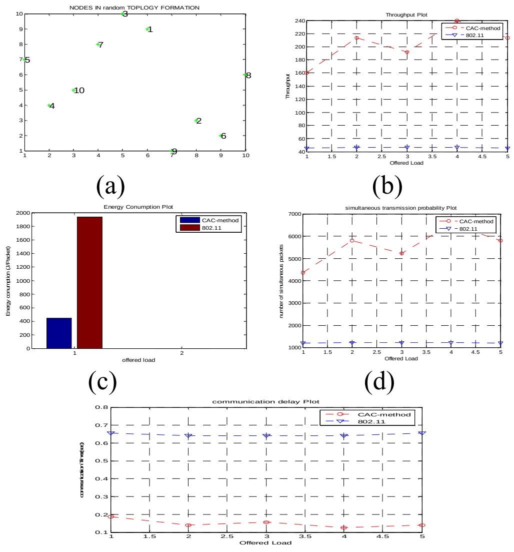


Figure 8: Communication Delay plot

The total delay hence observed for the communication of the total data packets when used for transferring under different offered load is observed. The delay of the proposed approach is observed to reduced than the conventional approach, as the channel is lower in congestion due to non generation of packet because of priorie interference knowledge. A similar case study is also carried out for a Randomly distributed network where the nodes are in random scattered Topology with Number of Nodes: 6, and Offered load 6



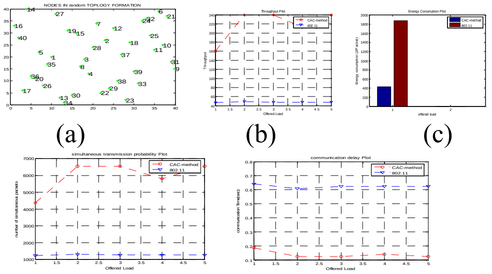
(a) (b)

(c) (d)

(e)

Figure 9: (a) scattered Network, (b): Throughput Plot, (c): Energy consumption plot, (d): Simultaneous transmission probability, (e): Communication delay plot.

For a Random Grid with, nodes= 25 , and offered Load = 8; the observations obtained are,



(a) (b) (c)

(d) (e)

Figure 10: (a) scattered Network, (b): Throughput Plot, (c): Energy consumption plot, (d): Simultaneous transmission probability, (e): Communication delay plot.

V. CONCLUSION

In this work, a power controlled access protocol for wireless ad hoc network is proposed. This protocol, called CAC, accounts for the multiple access interference, thereby solving the near-far problem that undermines the throughput performance in MANETs is proposed. CAC uses channel-gain information obtained from overheard RTS and CTS packets over an out-of-band control channel to dynamically bound the transmission power of mobile terminals in the vicinity of a receiver. It adjusts the required transmission power for data packets to allow for interference-limited simultaneous transmissions to take place in the neighborhood of a receiving terminal. The performance of the suggested protocol with that of the IEEE 802.11 scheme is carried out. simulation results shows that CAC based coding can improve the network throughput and, at the same time, achieve 50% reduction in the energy consumed to successfully deliver a packet from the source to the destination.

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