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Analysis and enhancement of pair-wise code assignment scheme used in Code Division Multiple Access protocol

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ABSTRACT

Code Division Multiple Access, which allows multiple users to access and transmit data over wireless channel simultaneously, is implemented using different code assignment schemes including Pair-wise Code Assignment. In this paper, the existing pair-wise code assignment procedure is enhanced and a new such scheme is presented with at most Δ codes, where Δ is the maximum degree of a network. In addition, a co-channel interference called secondary interference that exists in the existing schemes has been addressed and an interference free pair-wise code assignment procedure is proposed with at most Δ^2- c codes, where c is a constant. On simulation over different synthesized, actual and random networks, it is found that our scheme improves successful transmission rate and blocking probability by 17% and 12.5% respectively. Although the code requirement of the proposed interference free scheme is increased by 40%, it would improve the network performance.

1. Introduction

Wireless ad hoc network refers to an infrastructure-less system that consists of wireless devices with dynamically changing topology. Since the devices have the capability to communicate in ad hoc mode, protocol design for such networks is under the prime focus and several research articles are published in the literature. This type of networks, which operate as stand-alone or as an attachment to cellular/Internet, has extensive applications in different type of communications like personal networking, campus networking, battle fields, emergency and rescue operations etc. [1,2]. Since the network topology changes dynamically, it is difficult to design protocols that can address Quality of Service (QoS) issues. One important QoS is to design an efficient technique for Medium Access Control (MAC) [2,3], and the present paper designs a CDMA based MAC protocol that outperforms others. Below we give a brief overview of some of the important MAC protocols before presenting the proposed technique.

The standard IEEE 802.11 MAC, which is designed on the basis of CSMA/CA technique, is widely used for Wireless LAN (WLAN) implementation [4,5]. However, due to its demerits like exposed terminal problem, RTS collision etc., the network bandwidth is consumed unreasonably causing degradation of throughput, especially in denser networks. A MAC protocol must consider an efficient use of network resources for collision-free channel allocation in dynamic environment and channelization is one of the techniques that provides multiple access in the network without compromising the network resources [5,6]. It emphasizes on the channel allocation based on frequency, time or spreading codes. MAC protocols based on Frequency or Time Division Multiple Access (FDMA/TDMA) have incapability of simultaneous data transmission in all frequency bands or time slots respectively and thus, they have low channel utilization [7,8]. In CDMA based MAC, multiple users are allowed to transmit simultaneously using

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orthogonal spreading codes over the same allocated spectrum. It results in high channel utilization and better throughput than FDMA/TDMA based MAC and hence, gained high interest for wireless networks [9]. In CDMA, the users' data is spread with locally generated high rate spreading codes called chip sequence, and the intended receiver de-spreads the received signal with a specific spreading code for decoding data treating the remaining data as noise. As a result, it has been the choice of medium access technology in cellular systems, including the recently adopted 3G and 4G systems [10,11]. Spreading code protocol and code assignment govern the implementation of CDMA in spread-spectrum wireless networks. Although the spread spectrum protocols enhance the network performance by many folds, there is always a possibility of multiple access interference which can be reduced by efficient code assignment [12].

For an efficient CDMA based MAC, it is desired to have interference free simultaneous communication with less number of codes. In this paper, we tried to increase the efficiency of existing code assignment by maintaining the uniqueness and spatial reuse of the assigned codes, thereby minimizing the code requirement. We also observed a secondary co-channel interference in the existing code assignment techniques and modified the assignment procedure to avoid such interference and thus, enhanced the network performance.

The remainder of the paper is structured in following manner. Section 2 includes some preliminaries for different code assignment schemes and discusses the probable interferences. The related works are presented in Section 3. Section 4 presents the system model considered for the implementation of schemes. An efficient PCA based code assignment algorithm with lesser code requirement for the CDMA networks is proposed in Section 5. A modification of the existing PCA scheme is proposed in Section 6 for avoidance of secondary interference and presented an interference-free code assignment scheme. Both the algorithms have been simulated on some synthesized and benchmark networks, compared with the existing schemes and the results are given in Section 7. Finally, Section 8 concludes the paper.

2. Existing CDMA code assignment techniques and limitations

Since all the users share common spectrum in CDMA, the number of codes, which must not exceed a given bound, should be minimized [13]. The code assignment in CDMA network must be efficient and free from interference. Some of the common code assignment schemes and related interferences are discussed below.

2.1. Basic code assignment schemes

The aim of code assignment is to avoid frame collisions during simultaneous transmissions and reuse the assigned codes spatially. There are four different code assignment schemes:

(1) *Common Code Assignment* (*CCA*): all transmissions are done over a common spreading code.
(2) *Transmitter based Code Assignment* (*TCA*): each terminal is assigned a code such that no two neighbouring terminals have same code and the transmission will be done over transmitter's code.
(3) *Receiver based Code Assignment* (*RCA*): each terminal is assigned a code such that no two neighbouring terminals have same code and the transmission will be done over receiver's code.
(4) *Pairwise Code Assignment* (*PCA*): each pair of reachable neighbouring terminals is assigned a code with which the transmission is done.

TCA and RCA are considered as equivalent as they have same restrictions in the code assignment process and possess high code requirement. According to the Vizing theorem, the number of codes required in a network graph are at most $_{min}[\Delta(\Delta-1)+1, V]$ and $\Delta+1$ in TCA/RCA and PCA schemes respectively, where V is the total number of nodes and Δ represents the maximum degree of a graph [13].

2.2. Interferences in CDMA communication

Due to incorrect code assignment, interference may occur in a network causing degradation in performance. The basic interferences in CDMA based communication are summarized below [13]:

(1) Direct or primary interference- It occurs when two neighbouring nodes transmit simultaneously to each other using same code, as shown in Fig. 1(a). This may happen in TCA/RCA and PCA schemes.
(2) Indirect or secondary interference- When two transmissions are such that an interference at any of the participating receiver may occur. It comprises of two different types:
    (a) Two transmissions, which are unaware of the existence of each other, can transmit to the same receiver at the same time. As shown in Fig. 1(b), it occurs at node C and this type of interference occurs in TCA/RCA scheme. Similar interference as shown in Fig. 1(c) may occur at node C.
    (b) Interference similar to Fig. 1(c) may occur in PCA, when same code is assigned to two edges which are one-hop apart. It is shown in Fig. 1(d).

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