AntMAC: A Dynamic Control Channel Selection MAC Protocol Design for Cognitive Radio Ad Hoc Network

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***Abstract*- In this paper, we present an overview of the work-in-progress on the design of a newly proposed MAC protocol called AntMAC for Cognitive Radio (CR) application. Our design is aimed at improving the convergence time associated with selection of a control channel for Ad Hoc CR operation. In particular, we adopt the use of the bio-mimicry concept to develop swarm intelligence based mechanism for the selection of control channel in a heterogeneous, spatial, and time varying spectrum environment, with no pre-existing infrastructure. The long term goal of this work aims at improving Mean Time To Rendezvous (MTTR), throughput, and link utilization as compared to other existing designs.**

Index Terms— Cognitive Radio, MTTR, Rendezvous,

I. INTRODUCTION

With the recent surge in the deployment of wireless communication technology and the advent of newer bandwidth demanding multimedia services, spectrum scarcity is imminent. Yet still, Cisco VNI reported a further explosion of wireless traffic by 2018 [1]. The current static spectrum regulatory framework, wherein, an entire frequency band is exclusively allocated to specific services is inefficient. This static technique has failed to identify underutilized bands thereby resulting in apparent pseudo spectrum scarcity. Several spectrum surveys conducted across the world reveal spectrum underutilization in some licensed bands such as the very-high and ultra-high frequency bands (VHF & UHF) [2]. The trendy solution to spectrum scarcity is the usage of unlicensed devises by Secondary User (SU) in these underutilized bands. Federal Communication Commission (FCC) recently adopted this solution. The new field of research that enables this is the Cognitive Radio (CR) technology.

In CR, Dynamic Spectrum Access (DSA) is made feasible. However, spectrum access by opportunistic user (SU) must not interfere with the incumbent network, also referred to as the primary users (PU). Since DSA is still in its infancy stage, many research challenges remain, ranging from robust broad band sensing issues; access coordination that is, avoiding co-tier and cross-tier interference management issues among SUs and PUs, and Quality of Service issues, just to mention a few.

However, the main motivation for our work is to contribute towards developing a new and efficient MAC protocol for enhancing access coordination in CR DSA based Ad Hoc networks using Swarm intelligence based optimization techniques. By Swarm intelligence, we make reference to the mimicry of pheromone laying behavior of real ants to find the shortest route between their nest and a food source. This technique is popular in literature as Ant Colony Optimization (ACO).

Several MAC protocol designs have been proposed for centralized network architectures such as the IEEE 802.22 and Dynamic Spectrum Access Protocol (DSAP) [3]. However, few have been designed for distributed networks also known as Ad Hoc Networks. The absence of a central coordinator such as an access point or base station and the heterogeneous nature of the spectrum environment with spatial, and time varying availability have contributed to the difficulty in designing such protocols. The introduction of fixed or preselected control channels in MAC protocol design has remained the favourite approach in most works; however, this has generated more challenging issues such as control channel's robustness to PU activities, coverage and control channel security [4]. The focus here is to improve the mean time to rendezvous (MTTR) for a dynamic control channel selection. By rendezvous, we refer to the process of convergence which occurs when each SU seeking to communicate with another must first converge on a common channel to establish a link.

From related works, Horine & Turgut in [5] developed an algorithm for initial network set-up in which nodes seeking to establish connection randomly select available frequency and then emit attention signals on chosen channels. We note that the process of rendezvous was not bounded in time with respect to their analysis. DaSilva & Guerrreiro [6] proposed the use of a predefined non-orthogonal sequence to determine the order for visiting potential channels towards achieving rendezvous. The predefined sequence involved a random permutation of N available channels though no preference for rendezvous on best channel was obtained for MTTR. Similar approaches were adopted in [7, 8]. Also, authors in [6] derived a Modular Clock Algorithm (MCA) and a Modified MCA (MMCA) for solving the rendezvous problem and provided results to show some improvements. Consequently, in our work, we shall bench mark MTTR results of our developed design with that of some techniques mentioned above.

Our proposed MAC protocol design will be done in two phases; network setup phase and data phase. The network setup phase algorithm would involve neighborhood discovery through an intelligent channel hopping sequence. In the data phase, control information is first exchanged on the control channel and data are finally transferred on selected channels by the communicating CR pair.

II. PROPOSED DESIGN

A. Basic System Model Description

The entire spectrum band will be mapped into finite band spaces using a linear function. Here we shall consider the finite bands to consist of n non-overlapping orthogonal licensed channels. The PUs are considered holders of n channels indexed uniquely as 1, 2..., n. The CR network will consist of m nodes such that $m \geq 2$ nodes share the channels with the PUs in overlay architecture.

B. Network Setup Phase

The use of ACO methods for coordination and organization of network parameters has been observed in related work [9]. By drawing similarities, we propose the use of such technique in achieving the goal of coordination among CR Ad Hoc Networks (CRAHN) nodes. Towards this, we next describe our proposed algorithm for rendezvous.

Let A_{ij} be sets of available channels observed by m nodes such that $i \in n$ and $j \in m$ and it holds true that a common channel i.e $\cap A_{ij} \neq \emptyset$ exist. A system rendezvous occurs if all m nodes seeking to communicate converge on one of the common channel$i \in n$.

Our proposed ACO method deposit pheromone trails on the nodes of quality paths to reinforce the most promising channel in the channel hopping sequence. To achieve this, we present our proposed algorithm in Figure 1.

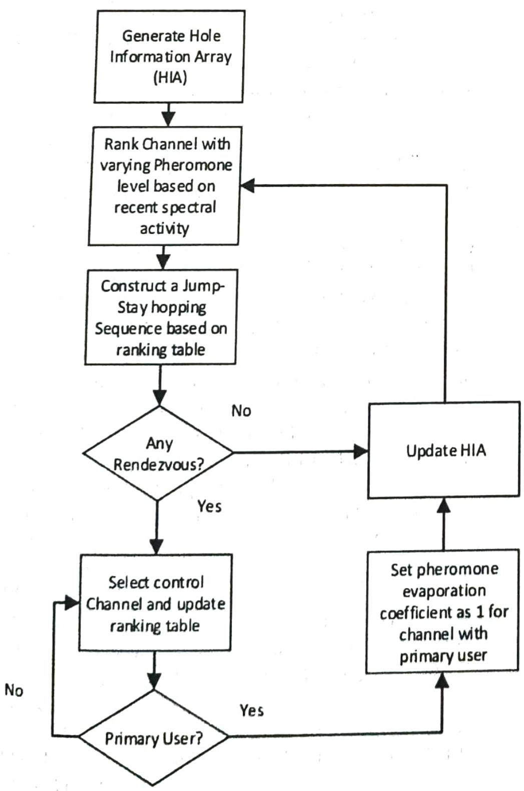

Figure 1: AntMAC Dynamic Hopping Algorithm

C. Data Phase

Once a common control channel has been established, control information such as request to send RTS, request channel list RCL and clear to send CTS can then be exchanged for the purpose of band aggregation. Data are exchanged over a converged channel.

III. ANTICIPATED RESULTS

We expect to improve on MTTR, throughput and link utilization. This would be achieved after development of the proposed algorithm and appropriate analysis. We note that PU activity will be modelled as a binomial random process and expect to limit the degree of PU interference based on the proposed designed algorithm.

IV. CONCLUSION

This paper presents a work-in-progress on the design of a novel AntMAC protocol for CRAHN. The proposed scheme will introduce channel aggregation as a function of slot time, packet size and bandwidth. This will be developed and analyzed using MATLAB and implemented in OPNET. Our design is intended to improve the Mean Time to Rendezvous (MTTR) of an Ad Hoc CR system with respect to other known approaches.

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BIOGRAPHY

Henry Ohize received his undergraduate degree in 2004 from Abubarkar Tafawa Balewa University Bauchi, and Master Degree in 2010 from Federal University of Technology, Minna both at Nigeria and He is presently studying towards his PhD at the University of Cape Town. His research interests include Wireless Sensor Networks, Cognitive Radio, Software Defined Radio, and Long Time Evolution Networks.