Cognitive Radio Mesh Network Testbed Implemented in GNU Radio with Batman-adv

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***Abstract*—Cognitive Radio Networks (CRNs) seek to use systems of Software Defined Radios (SDRs) to establish networks with flexible and intelligent physical and link layers. GNU Radio is an open source software tool set for working with SDRs and CRNs. Mesh networks are designed to allow for flexible and distributed network architectures to be self forming and to function without the need for centralized infrastructure. Batman-adv is a popular open source layer 2 mesh network protocol. Our work seeks to create a CRN by combinging GNU Radio with Batman-adv to create a fully open source cognitivie radio mesh network. The platform can work with USRP SDR devices to quickly prototype and experiment with cogntivie radio frameworks. Due to the flexibilty of Batman-adv and GNU Radio, programs acting above Layer 2 can utilize this network without any changes.**

***Index Terms*—Software Defined Radio, ad-hoc network, mesh network, Cognitive Radio Networks, Batman-adv, USRP, GNU Radio**

I. Introduction

Software defined radios (SDRs) have been around for many years. However, as the cost of SDRs continues to drop, the technology becomes much more accessible. Additionally, open source tools such as GNU Radio make developing for SDRs much easier. GNU Radio is an open source project to create an easy to use tool chain for creating SDR Projects. The GNU Radio Companion allows for GUI development of PHY and MAC layer protocols. The project itself is implemented in a combination of Python and C++ modules. Ettus research, a division of National Instruments, created the Universal Software Radio Peripheral (USRP) and the Universal Hardware Drivers (UHD). These tools have been integrated into the GNU Radio ecosystem, by Ettus and other developers.

Cognitive Radio Networks (CRNs) are networks made up of SDRs that are capable of making intelligent decisions on their own and adjusting parameters such as signal strength and operating frequency. Many Cognitive Radio scenarios are designed around the idea of ad-hoc or mesh networks. In these networks, all of the associated radio components are able to talk to each other either directly or by ”hopping” from one node to another until they reach their destination. The Better Approach to Mobile Ad-hoc Networks (BATMAN) project created the Batman-adv protocol. This layer 2 protocol has a fairly large community and is integrated into the Linux Kernel and OpenWRT project.

II. Related Work

The authors in [1] present an overview of several cognitivate radio transmission strategies and discuss the pros and cons of each method. In Mesh networks, the MAC protocols are essential to prevent data ”Deafness” where two nodes try to transmit at the same time on different frequencies, preventing communication. There are a few different standards for this discussed in [2].

It is reported that video on demand services make up about 27% of internet traffic. Therefore, for any Mesh Network to be successful, it would have to be able to handle this type of traffic. The author’s in [3] present a method for routing video data over multiple paths of the mesh to the user to increase effectiveness of data transmission. An improvement upon this algorithm is presented in [4].

A. Using GNU Radio for Cognitive Radio Application

Reaserachers have identified that the primary methods of creating a robust CRAHN is by ensuring that nodes optimize their use of physical space and allocated spectrum [5]. A testbed is needed in order to fully experiment with different algorithms to maximise these conditions. GNU Radio has been used by many different research groups to test various cognitive radio standards. The researchers in [6] created a simple multihop test bed using three USRP radios to relay data from one computer to another. A forth USRP acts as a primary user and attempts to block the signal. Their work focuses on using Reinforcement learning to allow for the hopping and does not discuss the routing protocol used in much depth. Much of the existing work done using USRPs and GNU Radio for Cognitive MANETs revolves around implementing different parts of the protocol from the ground up. In some papers the authors focus on the physical or mac layer [7]. There has also been work in developing new higher layer protocols for cognitive radio mesh networks such as work done to replace TCP with a more robust protocol [8] . These systems will usually react to frequency changes but some also change their topology based on power use [9].

There are several well known Cognitive Radio testbeds in use at different Universities. One major platform is the WARP platform from Rice University. This platform is made up of many custom components including the radio hardware itself [10]. Another platform is the Hydra platform developed at UT Austin. This platform uses GNU Radio to define PHY Layer parameters and the Click Modular Router to implement Layer 2 protocols.[11] The platform that most closely resembles ours is presented in [12]. However, this platform uses OLSR which operates on a layer above Batman-adv. Similarly, the University of California, Irvine and Boeing Corporation developed a testbed based off of USRP Radios and GNU Radio, but they implement custom MAC layers [13]. The ADROIT project was another platform developed in conjunction with DARPA. This project relied heavily on Click and GNU Radio for much of its functionality. [14] Though not deployed in a cognitive radio environment, the research in [15] presents metrics on Batman-adv itself and will be useful for seeing what decreases in performance are seen when using an SDR instead of a traditional Wi-Fi Router.

B. GNU Radio and Mesh Networks

In [16] and [17] the authors use GNU Radio as a way to verify the succesful use of algorithms for mesh networking.However, they do not specify that they are using SDR's and it seems like they use GNU Radio for simulation. GNU Radio has also been used with the USRP to create a device capable of communicating with both Bluetooth and WiFi devices. However, this does not create a mesh network or attempt to bridge communication between the two protocols. However, a significant amount of information about communicating with each type of network is presented [18]. This also presents the concept of Police Nodes which monitor traffic in an attempt to block out improper use of the spectrum.

Research has been done in using the GNURadio toolset along with the USRP to test Mesh Network routing protocols. One test used varied data transmission rates to exploit opportunities in physically close proximity Nodes [19]. The GNU Radio toolset was also used to test using cognitive radio within a mesh network. USRPs were used as nodes trying to communicate on a "shared" frequency. A separate USRP was used to replicate a primary user, or one that had a license to operate in that spectrum. Whenever the primary user began to transmit in the spectrum, the other nodes would use reinforcement learning to move to an unoccupied channel automatically and continue transmitting [6]. A similar test bed is also presented in [7].

In [20] researchers at UCSB investigated using an SDR with GNURadio to improve upon the needs of rural networks. The topic was found while search for mesh networks but seems to be mostly focused on non-mesh applications. They created the solution WhiteRate which allows for the changing of the PHY layer without changing any other components.

In [21] the authors utilize GNU Radio to implemenet a PHY layer that is able to broadcast and recieve on several channels simultaneously. The paper tests using 2 USRP boards and also simulates a larger scale.

The CONFINE platform uses Batman-adv as the routing protocol for their mesh network testbed. However, this testbed does not utilize GNU Radio or any cognitive radio tool sets. [22] Batman-adv was also a key component of WiBed, a project to create a COTS mesh test bed using low cost wireless routers. [23] [24]

III. Design

Then comes the Design

IV. Results

Now we talk about the data collection

V. Limitations and Future Work

We then talk about the assumptions and such

VI. Conclusions

Nearly done

VII. Acknowledgments

We would like to thank the academy

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