Initial Draft of SDR, SDN, and Cognitive Radio Literature

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I. RTL-SDR

The RTL-SDR is a recent tool discovered by the DIY and hacking community. Its original purpose is to be used as a digital TV tuner. However, it was discovered that this system could also be used to general SDR purposes. There is now a large community dedicated to using this tiny SDR to recieve various different signals. Prior to the creation of the open source drivers for the RTL-SDR, the most popular devices for SDR came from USRP. The USRP devices are fantastic products, but cost at least $1,000 and can cost quite a bit more with additional features. The RTL-SDR is based on rhe Realtek RTL2832U chip. This device can often be purchased for between $20 and $30 [1]. The range for the RTL-SDR is typically 64 MHz to 1700 MHz, however this varies depending on which tuner the manufacturer paired with it. The authors in [1] paired the RTL-SDR with a mixer in order to lower the range all the way to DC. For this, they used the NE6062AN chip.

Starting with Release 2013b, MATLAB/Simulink now have a support package that targets RTL-SDR devices. In Simulink, the package contains a single block called "RTL-SDR Receiver." This block allows the user to tune the center frequency, change the tuner gain, set the sampling rate, and alter the frequency correction factor. The block can then output the complex envelope (IQ) of the recieved signal in both floating point and integer formats[2]. Due to the open nature and low cost of the RTL-SDR, the authors in [3] propose using this as a tool set for teaching DSP and Communications principles to students.

When the cost of the system is far less than that of a textbook, it is easy to see why this could become a valuable learning tool for many students. UC Berkley has already begun to use the RTL-SDR as one of the project assignments in their digital signal processing course. There have been efforts to use the RTL-SDR with the popular Raspberry Pi computing platform. However, at least with the B+ model there is not enough power available to process the signal. Instead, it has to be used as a TCP server that is then able to forward the data on to a more powerful computer[4]. Currently, it does not appear as though anyone hast tested this with the Raspberry Pi 2 microcomputer. Other work has been done to estimate the cost savings of using a USRP in conjunction with several RTL-SDRs to replace existing DSP lab infrastructure [5].

The most unfortunate downside to using the RTL-SDR is that it is unable to transmit. However, researchers in [6] proposed a system in which a USRP SDR is used as a master device that broadcasts out to a series of slave nodes that can only listen for information. In their system they used a tool called GStreamer to pass video data into GNURadio. This information was then broadcast to multiple computers in a room running an RTL-SDR with GNURadio. The nodes were all able to view the video stream in near real time.

It is interesting to note that an IEEE search for the RTL-SDR turned up 6 results, but a search on Funcube Dongle returned 0 results. These devices were in competition with one another for awhile, but the Funcubes prices continues to rise as the RTL-SDR's continues to drop. The Funcube has a larger range than the RTL-SDR but it seems the cost is still the key factor.

II. GNU RADIO AND MESH NETWORKS

In [7] and [8] 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 [9]. 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 [10]. 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 [11]. A similar test bed is also presented in [12].

III. GAMIFICATION

There are a number of TV white spaces in rural communities. That is, empty spaces left for the UHF TV spectrum that dont actually have anything broadcasting on them. The team in [13] created a Raspberry Pi system that is able to scan for these blank spaces, and geotag them. Using an RF Explorer and GPS, the system is able o scan for open bandwidth and then tag the location. The authors mention wanting to put these

units in the hands of as many people as possible to create a distributed measuring system.

The authors in [14] present a game called Spectrum Wars. This game involves two teams competing to send data in a crowded environment. Players can vary Frequency, Bandwidth, and Gain of the signal. The first player to successfully transmit the signal wins the points. The author's present an earlier version of their work in [15].

IV. Cognitive Radio based Mesh Networks

The authors in [16] 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 [17].

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 [18] 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 [19].

V. Low Cost SDR and Cognitive Radio Platforms

The Communications Research Center in Ottawa, Canada has created a cognitive radio platform that they have nicknamed CORAL. This is a custom created platform that is capable of performing cognitive radio type tasks at the 2.4GHz and 5GHz license exempt bands.[20]. Further research done in [21] introduces a tool called CogFrame. This platform uses traditional computers and wifi cards to create a congitive mesh network capable of running tests. They compare the tool to a test bed made of USRP's as well as pure simulations and found it to outperform the simulation and be on par with the USRPs. The authors in [22] provide a wonderful overview of everything one could want to know about cognitive radio. Including some major platforms that exist such as WARP from Rice University, BEE From Berkley, and CORAL from the communications research center in Canada. They also present their own platform based of the BeagleBoard. This article would be great for anyone just starting out to read. A group from Germany has created a cognitive radio based wireless microphone system [23].

VI. Cognitive Radio and Robots

The authors in [24] discuss using a distributed group of spectrum sensing tools with a UAV to find a target using RF localization. They use a technique called compressive spectrum sensing to make the task less computationally intensive. They then have a group of sensors attempt to find the source of the RF signal and then work to find it using localization techniques. The group performed MATLAB testing. They also ran some brief field tests without a UAV using GNURadio and USRP SDRs. The authors in [25] discuss the benefits of using a cognitive network with a UAV. The discuss many of the benefits that the technology would bring including security.

VII. Cognitive Radio Standards

In [26] the authors discuss a MIMO scheme for transmission of packets using cognitive radio. The system is then simulated and results are prsented. In [27] the authors discuss using a USRP device with GNURadio to test out several routing algorithms.

VIII. Mesh Networks and Robots

Researchers have begun to examine the problems of using UAVs to communicate on a mesh network. Part of the problem lies in the fact that communicating with a moving node can be difficult. One way to combat this is to use multiple nodes on the UAV that exploit the spatial and temporal diversity of the wireless channel.They ran their tests on a 110" wingspan UAV with 4 mesh nodes on it. They used the 802.11 adhoc mode for their network. [28] The same team presented a test of creating a network with a UAV using the Load, Carry, and Deliver paradigm. This UAV would "pick" up data from one node, fly to the next node, and then drop it off. [29]

Work present in [30] demonstrates a great overview of the current "state of the art" in regards to UAV based networking. The author discusses the main routing formats and many of the challenges that go along with UAV network. This should be seen as a good starting point for people first learning about this topic. In [31] the author's discuss the concept of a cloud computing and software, platform, and infrastructure as a service environment. They discuss abstracting out significant parts of the UAV system, such as navigation, so that they can be done in the cloud. This would allow for most of the computation to be done in a single format off board, allowing for easier integrationg of heterogeneous swarms of robotics.

IX. Signal Processing Techniques

In [32] H.T. Kung presents partial compressive sensing, a signal processing technique which reduced the frequency needed to sample a signal. This conecpt is presented again by this research group in another paper discussing using it for communicating within a mesh network.

X. Applications of Cognitive Radio

The authors in [33] present a cognitive radio based wireless cabin management system for airplanes. The team created an actual system based off of an FPGA and a transciever to demonstrate the basic functionality needed by an airplane cabin management system. Their paper also presents a detailed testing plan and the results of the test.

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