A Cognitive Radio Multimedia Network Testbed for Multimedia Communication

System Requirements Review

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System Description and Overview

The purpose of this project is to test and develop a working network testbed utilizing Software Defined Radio (SDR) technologies as the primary means of data communications. The testbed will be the underlying system for further research within the scope of radio communications. The primary goal specified by the customer is to achieve reliable data communications between two systems connected to this network.

The **Co**gnitive Radio **M**ultimedia N**e**twork **T**estbed for multimedia communication (COMET) comprises of a network of Universal Software Radio Peripherals (USRP) configured to transmit data within the testbed. The USRP N210 contains an ethernet port which allows for 1Gbps ethernet connectivity. This can be utilized to group all USRP devices to an ethernet switch to route data transmission within the network. In addition, a client and server workstation will be connected to the switch to send and capture this information for the user. These workstations may run with a Windows or Linux operating system and will contain the USRP Hardware Driver (UHD) to communicate with the USRP. Figure 1 demonstrates the proposed system diagram for COMET:

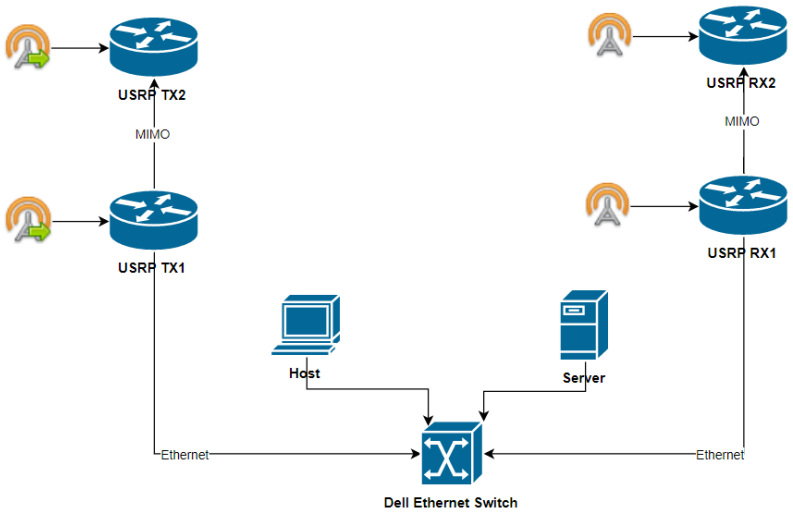

Figure 1: Network Map Version 1.0

Requirements

Customer Requirements

In order for the project to be a success, there are certain requirements given by the customer that will need to be met. Overall, there are two main requirements. The first will be to setup a network testbed for multimedia communication. This will entail using the USRP N210 software-defined radio device to design and implement a reliable communication network. This network should be able to transmit and receive data between USRP devices over a common, reliable frequency.

The second requirement will be to improve this testbed to implement even more networking devices. This will be adding more transmitter and receiver modules in the shape of more USRP N210 devices that will be able to communicate synchronously.

Table 1 further illustrates these requirements in a tabular format.

No.	Customer Requirement	Requirement Description
1	Setup network testbed for multimedia communication	Using the USRP N210 SDR device, design and implement a reliable communication network capable of transmitting and receiving data from one device to another over a common but reliable frequency.
2	Improve the testbed to implement more networking devices	Improve on the base testbed by adding multiple transmission and receiving components that can communicate synchronously.

Table 1: Tabular Representation of Customer Requirements

Engineering Requirements

Translating the customer requirements into engineering terms will involve a few more steps. To fulfill the first requirement, a network will first have to be mapped out in which data can be sent to and from the given USRP devices and workstations. This step will involve careful inspection and documentation using available charting tools such as Microsoft Visio.

The first requirement will also require one USRP device to act as a transmitter and another device acting as a receiver. For the data to be wirelessly shared, the transmitter will need to send over a specified frequency and likewise received by the receiver over the same frequency. This frequency must be within the 2-2.4GHz range, but can communicate on a higher frequency's if required. The range is a commonly used frequency range; therefore, transmission errors will be expected. The data throughput of this configuration will be recorded and analyzed to assure steady communications. The system's reliability will be prioritized mainly during the second semester.

To fulfill the second customer requirement, additional transmitter and receiver USRP devices will be added to the system using a Multiple Input Multiple Output (MIMO) configuration. MIMO configuration allows for the optimization of network speed by synchronizing device computation between multiple units, rather than just one. With that in mind, it is unknown just how many more devices will be implemented in the project. The addition of more devices will be limited to the 24 ethernet ports provided on the ethernet switch.

The switch will be incorporated into the system by attaching the main transmitter and the main receiver to it (i.e. the first transmitter and receiver in the system). To further connect all the devices in the network testbed, all transmitters will be connected through the MIMO port, along with all receivers. The built-in support will allow each connected device to operate synchronously upon software implementation. Figure 1 in the System Description and Overview illustrates this setup.

Table 2 further illustrates these requirements in a tabular format.

Customer Requirement No.	Engineering Requirement No.	Engineering Requirement Description	Justification/ Comments	Test Method
1	1.a	Map out a network in which one end user sends a file through the Transmitter and is received and shared to the other end user through the receiver over the 2 - 2.4Ghz frequency range.	Transmission errors expected over common frequency channel, reliability aspect covered in second semester.	Inspection
	1.b/c	Configure one USRP to function as a Transmitter/Receiver. Benchmark sampling results of transmitted and received packets.	In order for data to be wirelessly shared, one USRP must act as a transmitter to send data over a specified frequency and another to capture that transmission	Demonstration/ Analysis
2	2.a	Add additional transmitters and receivers through MIMO configuration.	MIMO (Multiple Input Multiple Output) allows for optimization of network speed by synchronizing device computation between multiple units rather than depending on one.	Test/Inspection
	2.b	Attach main transmitter and receiver to ethernet switch to connect all devices within network testbed. Benchmark sampling results of transmitted and received packets	Number of added devices will increase throughout the year; therefore, a network switch will be utilized to accommodate all device traffic within the network.	Demonstration/ Analysis

Table 2: Tabular Representation of Engineering Requirements

Constraints and Applicable Standards

One of the major restrictions to the project is the rules and regulations set forth by the FCC (Federal Communications Commission). Title 47, Chapter 1, Subchapter B, Part 27 sets forth the restrictions on communication frequencies and who can use which frequencies. This restricts which frequencies can be used for communication by the USRP. This range was suggested as 2000MHz-2690MHz by the customer, which meets the standards set by the FCC. This range was set, as the customer preferred that the project use the UHF (Ultra High Frequency) band, which

extends to 3000MHz, rather than going into the SHF (Super High Frequency) band for communication between the USRP devices.

Another constraint is the restriction of the project to the USRP N210 SRD. This limits what can be used for programming the device, as well as limiting throughput rates based on the devices capabilities. For system programming, the FPGA firmware can interpret low-level C code. The other drawback of the USRP is that its Ethernet driver only supports a speed of 1Gbps. This limits what cables can be used to communicate with the device, as any cable rated for higher speeds than the limit will be wasted potential.

Equipment Estimate

At a minimum, the project will require four USRP N210 devices. This will allow for two transmitters and two receivers, as depicted in the initial COMET system diagram. Each of the USRP devices needs to be outfitted with a RF Daughterboard SBX 400-4400 MHz RX/TX. This sets the range of frequencies usable by the device, as well as setting the possible functionalities. Each USRP will also be equipped with a LP0965 antenna. These antennae will dictate the possible range of communication for the device.

The project will also require the use of two desktop PCs, preferably using a Linux system, though a windows system will also interface with the USRP. In the first phase of the project, having two PCs will allow for testing of the USRP interaction with one device set as a transmitter, and another set as a receiver. For the second phase of the project, a Dell Networking 5524 Gigabit Ethernet Switch will be needed. This will allow for the USRP devices to be connected and ready to communicate with the host PC and server in phase two.

There are two primary software required for both phases of the project. One of the programs is GNU Radio. This software provides a GUI for USRP coding that will implement graphical system layouts into C code for the FPGA to interpret. The other required software is USRP Hardware Driver, or UHD, which allows for system programming and configuration. Luckily, both programs are open-source and can be easily installed on both Windows and Linux systems.

Initial Plan and Schedule

The tentative group plan can be divided into two phases, which will be accomplished within each of the two course semesters. The first phase will attempt to build a working transmitter and receiver module that will be applied to the network testbed. The second phase will use these modules and introduce the implementation of the network switch and MIMO configuration to improve on the first phase system.

Phase 1

The plan for phase one will consist of heavy research into the field of SDR and radio communications. This research will help prepare for the eventual implementation of a transmitter and receiver on GNU radio. It is essential that all team members can fully grasp the fundamentals of radio communications, which is why each member will be assigned individual research tasks. Upon finishing the research and requirements tasks, the implementation of the transmitter and receiver will begin, ideally being finished before the concept review. Finally, the modules will be implemented into a prototype testbed, or Phase 1 testbed, before the preliminary design review. This prototype will be replicated and scaled to the final testbed for the following semester. The current schedule can be seen in Table 3 located below:

Task	Team Member(s)	Time	13-Oct	20-Oct	27-Oct	3-Nov	10-Nov	17-Nov	24-Nov	1-Dec	8-Dec
Draft Final Report for System Requirements	Eric	2 -4hrs									
Configure USRP drivers on host PC	Eric	1 hr									
Configuration Documentation	Eric	2 hr									
Write-up (Tx Research)	Kevin	2 hr									
Write-up (Rx Research)	Jeff	2 hr									
Write-up (MIMO hardware testbed Research)	Toby	2 hr									
Research and Design a Transmission schematic on GNU Radio	Kevin, Eric	10-20 hrs									
Research and Design a Receiver schematic on GNU Radio	Jeff, Toby	10-20 hrs									
Concept Design Review	Eric	10-20hrs									
Integrate Transmitter/Receiver Phase 1 Testbed	Eric, Toby	5-10 hrs									
Test and Document Transmitter/Receiver Phase 1 Testbed	Kevin, Jeff	5-10 hrs									
Preliminary Design Review	Eric	10-20 hrs									

Table 3: COMET Project Gantt Chart for Phase 1

Note that all reports will be a collaborative effort by all team members, but will be edited and submitted by the Team Lead, Eric Pires.

Phase 2

The final phase of this project will continue to improve on the finished prototyped testbed. This will include adding several more pairs of USRP devices into a MIMO configuration. This will also include incorporating a network switch to interface within the testbed. The planning for this phase will ultimately be decided upon the outcome of Phase 1. If Phase 1 completes as expected, then Phase 2 will immediately commence the final implementation of the testbed. If Phase 1 is delayed, then these issues will be the top priority at the beginning of the spring semester.

To accommodate the time lost between the long break, group communication will be maintained and might consist of several face-to-face meetings, depending on each member's holiday schedule. If Phase 1 is fully completed, then such communications will be less necessary. However, if the phase is a failure, then time will be taken to strengthen fundamental skills in preparation of the second semester.