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Major Goals: The project is focused on building an infrastructure that can be used for designing and testing wireless, communication, network, and security designs. The infrastructure consists of computing and radio components. The PI has moved the infrastructure from the original Awardee, University of Memphis, to the PI's new Institution, University of South Florida, under the permission of the University of Memphis.

The infrastructure has been built to achieve the fundamental capability of high-speed wireless communication, multiple-input and multiple-output (MIMO) wireless communication, and high-fidelity in-lab wireless network emulation. The infrastructure enables both education and research activities in the broad area of wireless communication, networking and security designs.

This report summarizes how the system components and setups to achieve the capability for both education and research purposes. In particular, the report describes detailed system setups, some initial design and testing results, as well as potential use of the infrastructure at University of South Florida in the future.

Accomplishments: During the course of the project, a balanced purchase plan is adopted between cost efficiency and achieving high capability within the given budget. The final infrastructure consists of the following major computing and radio components.

Eight software-defined radio platforms as the radio front end. Universal Software Radio Peripheral (USRP) X300 is selected to be the radio front end that is capable of processing up to 120MHz bandwidth wireless signals with carrier frequency up to 6 GHz. It is ideal from high-speed wireless communication, such as Orthogonal Frequency-Division Multiplexing (OFDM) and MIMO.

Three high-performance workstations. The workstations features 10Gbps Ethernet interfaces, large memory, and multi-core CPUs. Two are used primarily to connect to the radio frond end. The 10Gbps Ethernet interfaces between the workstations and the radio front end enable high-throughput baseband data streaming from the radio front end to the workstations, where physical-layer baseband processing as well as upper layer protocols are designed and implemented. In addition, two workstations have four 10Gbps Ethernet interfaces each such that four USRPs can be connected to each workstation to achieve the MIMO capability. Because each USRP can be equipped with two antennas. The infrastructure is able to perform 8-antenna point-to-point MIMO communication.

Micro-cloud and wireless channel emulator. An eight-node micro-cloud has been purchased to connect eight USRP X300s to form a networking environment. In addition, the radio interfaces of USRP X300s can be connected to an eight-channel wireless channel emulator to emulate a multi-hop wireless network scenario. This multi-hop wireless networking capability is in addition to the 8-anntenna MIMO communication capability.

Laptops and desktops. They are used for less critical data processing, testing, analysis with the radio front end as well as preliminary design or simulation before moving to full design and implementation at the radio-enabled workstations/micro-cloud. In addition, two laptops can be also used as the mobile stations when mobility design or testing is necessary.

GNU Radio software packages. Currently, all the baseband data processing algorithms and functions are designed in the open-source GNU radio software package. We are designing our own modules to achieve all the capabilities of the infrastructure

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Zhuo Lu
Person Months Worked: 1.00 **Funding Support:**
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Other Collaborators:

Final Project Report

1. Basic Information

Project Title: An Infrastructure for Designing and Testing High-Fidelity Wireless Network and Security Solutions.

Project Number: W911NF-15-1-0388.

PI: Dr. Zhuo Lu (zhuolu@usf.edu)

Current Institution: Electrical Engineering, University of South Florida (Since 8/2016)

Previous Institution: Computer Science, University of Memphis (8/2014 – 8/2016)

2. Introduction

The project is focused on building an infrastructure that can be used for designing and testing wireless, communication, network, and security designs. The infrastructure consists of computing and radio components. The PI has moved the infrastructure from the original Awardee, University of Memphis, to the PI's new Institution, University of South Florida, under the permission of the University of Memphis.

The infrastructure has been built to achieve the fundamental capability of high-speed wireless communication, multiple-input and multiple-output (MIMO) wireless communication, and high-fidelity in-lab wireless network emulation. The infrastructure enables both education and research activities in the broad area of wireless communication, networking and security designs.

This report summarizes how the system components and setups to achieve the capability for both education and research purposes. In particular, the report describes detailed system setups, some initial design and testing results, as well as potential use of the infrastructure at University of South Florida in the future.

3. System Setups

During the course of the project, a balanced purchase plan is adopted between cost efficiency and achieving high capability within the given budget. The final infrastructure consists of the following major computing and radio components.

- Eight software-defined radio platforms as the radio front end. Universal Software Radio Peripheral (USRP) X300 is selected to be the radio front end that is capable of processing up to 120MHz bandwidth wireless signals with carrier frequency up to 6 GHz. It is ideal from high-speed wireless communication, such as Orthogonal Frequency-Division Multiplexing (OFDM) and MIMO.

- Three high-performance workstations. The workstations features 10Gbps Ethernet interfaces, large memory, and multi-core CPUs. Two are used primarily to connect to the radio frond end. The 10Gbps Ethernet interfaces between the workstations and the radio front end enable high-throughput baseband data streaming from the radio front end to the workstations, where physical-layer baseband processing as well as upper layer protocols are designed and implemented. In addition, two workstations have four 10Gbps Ethernet interfaces each such that four USRPs can be connected to each workstation to achieve the MIMO capability. Because each USRP can be equipped with two antennas. The infrastructure is able to perform 8-antenna point-to-point MIMO communication.

- Micro-cloud and wireless channel emulator. An eight-node micro-cloud has been purchased to connect eight USRP X300s to form a networking environment. In addition, the radio interfaces of USRP X300s can be connected to an eight-channel wireless channel emulator to emulate a multi-hop wireless network scenario. This multi-hop wireless networking capability is in addition to the 8-anntenna MIMO communication capability.

- Laptops and desktops. They are used for less critical data processing, testing, analysis with the radio front end as well as preliminary design or simulation before moving to full design and implementation at the radio-enabled workstations/micro-cloud. In addition, two laptops can be also used as the mobile stations when mobility design or testing is necessary.

- GNU Radio software packages. Currently, all the baseband data processing algorithms and functions are designed in the open-source GNU radio software package. We are designing our own modules to achieve all the capabilities of the infrastructure.

4. Initial Design and Testing Results

We have provided some initial design and testing in the infrastructure, as illustrated in Figure 1.

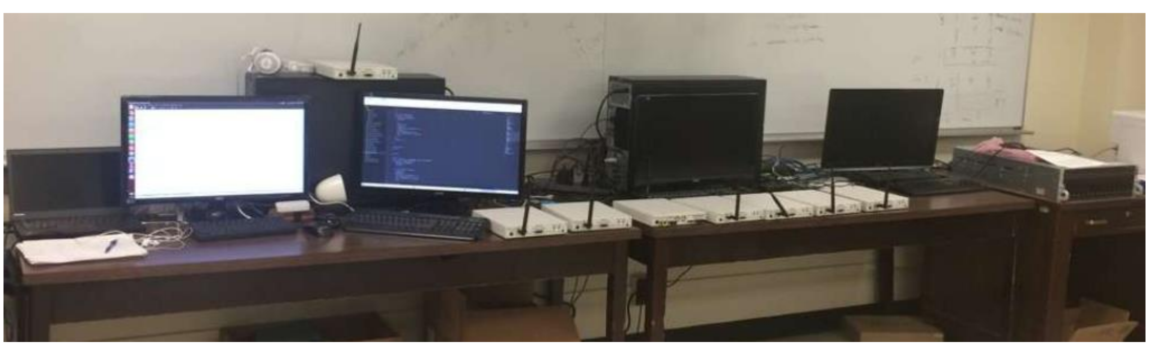

Figure 1: Initial Testing of the radio interfaces.

As the initial use of the infrastructure, we are designing and implementing an improved physical-layer/MAC-layer version of IEEE 802.11 for both education and research purposes. We designed the entire architectures of OFDM transmitter and receiver based on the open-source GNU Radio software for the improved IEEE 802.11 design. We are able to develop a generic IEEE 802.11 computing software template in the infrastructure to adopt various IEEE 802.11 standards by tuning parameters, such as carrier frequency and encoding scheme. Figure 2 shows the design scheme of the OFDM transmitter. Figures 3 and 4 show the design schemes for synchronization and demodulation at the OFDM receiver, respectively. All the designs have been implemented using GNU Radio.

As shown in Figure 3, we implement the Schmidl and Cox (S&C) synchronization algorithm for OFDM packet synchronization at the receiver. This method of synchronization is considered very robust and efficient for OFDM communication in the literature. It works by appending specially generated S&C training sequences to the data at the transmitter. With the help of the first OFDM symbol it produces a triggering signal to find the starting time of a packet at the receiver. During our experimental tests, we find that the infrastructure well supports the implementation of this algorithm on IEEE 802.11.

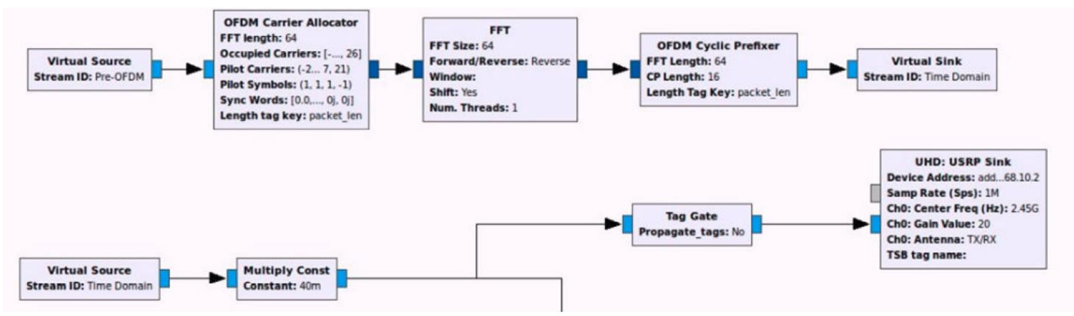

Figure 2: Design of OFDM Transmitter.

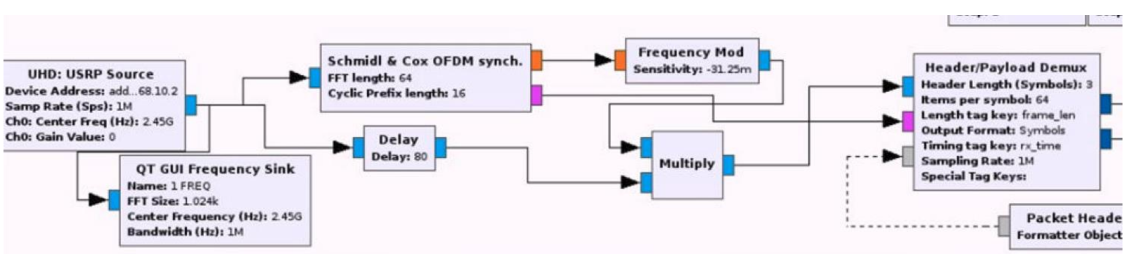

Figure 3: Design of Packet Synchronization at OFDM Receiver.

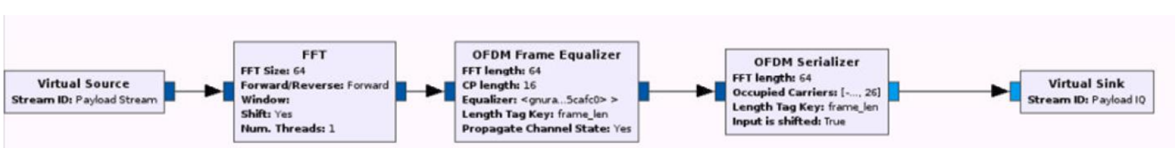

Figure 4: Design of Packet Demodulation at OFDM Receiver.

FFT size	64
Packet length	96
Cyclic prefix	16
Sampling Rate	1 Msps
Modulation	BPSK, QPSK
Central Frequency	2.45 GHz

Table 1: Testing Parameters in initial OFDM experiments.

Table 1 shows the parameters in our experiments, and Figure 5 shows the real-time acquisition of OFDM packets based on the implemented S&C algorithm in the time domain. From Figure 5, we can clearly see that the position of an arriving OFDM training sequence is acquired at each peak value shown in Figure 5. Therefore, the receiver can very accurately locate the starting point of an OFDM packet then start the demodulation process shown in Figure 4. The experiment results indicate that the infrastructure built in this project well supports real-time OFDM transmission and receiving via coding and decoding at the software level supported by the computing components.

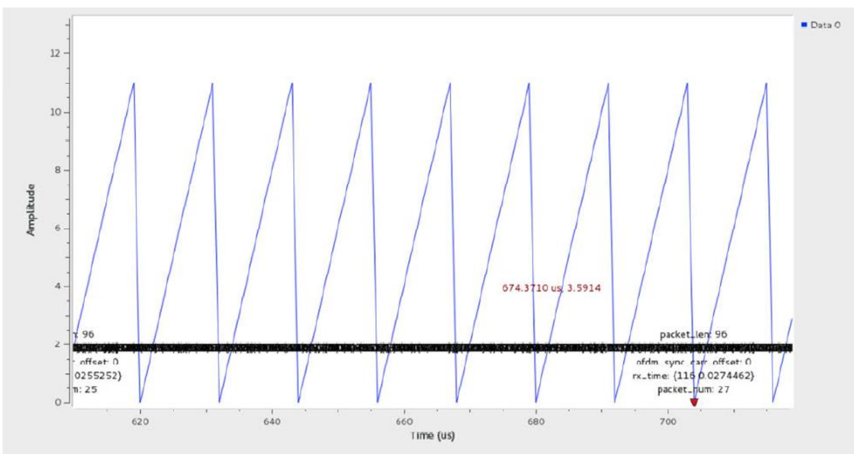

Figure 5: Real-time acquisition of OFDM packets in the time domain during experiments.

5. Potential Use

Our initial test results show that the infrastructure is well capable of efficient OFDM communication based on efficient data exchange between radio and computing components. As progressive testing shows that most devices are working efficiently and stably, we plan to carry out more research and education activities on the infrastructure and fully use its capability. There are a few potential activities that we plan to carry out on the infrastructure.

- High-efficiency MIMO communication with security issues. The infrastructure is able to perform 8-antenna point-to-point MIMO communication. This provides unique capability to investigate security issues associated with MIMO systems with a large number of antennas. For example, security key establishment design has been explored in the literature. However, most of the experiments were performed with a limited number of antennas (e.g., 2 – 4 antennas). Security key establishment based on 8-antenna MIMO systems could potentially show great efficiency during key establishment leveraging the spatially uncorrelated property in wireless channels.

- Multi-hop wireless network and security protocol design. It has been historically cumbersome to field-test multi-hop wireless networks because their presence in complicated environments. This infrastructure enables high-fidelity in-lab multi-hop wireless network test. The PI currently has a project related to multi-hop wireless network design and security, and plans to perform real-time experimental testing in the infrastructure when the design in the project is well evaluated in theory and simulations.

- Going beyond GNU Radio software. In the future, we plan to seek the feasibility of developing standalone software for the infrastructure to further improve data processing efficiency between the computing components and the radio components.

The infrastructure is currently in use in the related research and education activities in the area of wireless communication, networking and security at University of South Florida. Given its current strong capability, we expect that computing and radio components in the infrastructure can be efficiently used for at least 5 years and 8 years, respectively.