Open-Source Prototyping of Advanced Wireless Systems for Smart Agriculture and Connected Rural Communities

DESIGN DOCUMENT

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Executive Summary

Development Standards & Practices Used

Agile

Summary of Requirements

- Implementation of PRKS Algorithm
- Implementation of pktRT Algorithm
- Applying the above algorithms within the TVWS spectrum
- Developing a Proof of Concept application using the above implementations that relates to smart agriculture

Applicable Courses from Iowa State University Curriculum

CPRE 308, COM S 311, CPRE 430/530, CPRE 489, CPRE 548X

New Skills/Knowledge acquired that was not taught in courses

TVWS (TV-White Space), PRKS Algorithm, pktRT Algorithm, wireless kernel development, wireless networking protocols.

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List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1 Introduction

1.1 Acknowledgement

We would like to express our great appreciation to Prof. Hongwei Zhang and Dr. Matthias Sander-Frigau, for their patient guidance, enthusiastic encouragement and useful critiques of this senior project.

1.2 Problem and Project Statement

Rural regions are home to many industries such as agriculture, renewable energy and manufacturing, and they are major sources of food and energy for our society. For instance, the US agriculture and food sectors alone contribute more than $750 billion to the national GDP every year. However, rural regions are subject to growing challenges such as population shrinkage and labor shortage, the need to feed a growing population and food demand while subject to climate changes, and the rural-urban education gap. One basic enabler for addressing these challenges and for ensuring the prosperity of rural regions and communities and our society in general is broadband rural connectivity. Rural broadband is the digital superhighway for the broad rural communities and industries, but 39% of the rural US lacks broadband access, and most farms are not connected at all. Through this project, we are going to develop and prototype advanced wireless solutions for smart agriculture and connected rural communities. We are going to use cutting-edge TV white space (TVWS) wireless platforms and advanced wireless algorithms. At the end of this project, we hope to accomplish a spiral evaluation and refinement of the aforementioned novel 5G wireless solution for smart agriculture and connected rural communities.

1.3 Operational Environment

We will be using the Qualcomm Atheros QCA9533 chip. It is a highly integrated and feature-rich IEEE 802.11n 2x2 2.4 GHz System-on-a-Chip (SoC) for advanced WLAN platforms.

1.4 Requirements

Functional Requirements: The basic of our wireless communication is based on TV Whit Space(TVWS). Then, for implementing this wireless solution to rural, we need algorithms to support. In which we are utilizing the PRKS and pktRT algorithms created by Dr. Hongwei Zhang. This ensures the reliability for the wireless communication and the time guarantee in real time packet transmit. Then for the software requirement, we are using the OpenWrt on top of QEMU which was designated to simulate MIPS embedded devices.By simulating the chip we are using, ensures us to test our code functionally before actually did the field test. Lastly, we will need physical hardware to apply our solution.

1.5 Intended Users and Uses

Our major customer/user will be within the smart agriculture industry in rural communities. In the US, tons of industries are based in rural areas, as well as agriculture. A big number of them especially farms have a lack of broadband connectivity or have no reception at all. So if these

regions can have a reliable wireless network setup, there will be a big progress towards smart industry/ agriculture.

1.6 Assumptions and Limitations

Assumptions: Our prototyped solution will be work at rural regions who requires a reliable wireless connectivity;

Limitations: Limited to implementation of TVWS Spectrum; Any noise / interference in TVWS.

1.7 Expected End Product and Deliverables

– By the end of the Project, we will be able to create a prototype of a reliable wireless solution for rural regions. This prototype will be a good starting point for future advanced rural wireless network development.

– The prototype is expected to be done by March 2020.

– If the prototype works fine, we might be able to have it applied on physical wireless devices. This will enable rural broadband for the region that is lack of connectivity. Which will enhance the prosperity of rural regions as well as the society as a whole.

– The solution enabled device might be delivered by April 2020.

2. Specifications and Analysis

2.1 Proposed Design

During the process of virtualizing OpenWrt on local computers, we installed VirtualBox application on our computers and set up the network adaptor and SSH in order to provide a platform for the prototype to run. By implementing Agile model to this process, we can increase our efficiency during our workflow.

When it comes to understanding the advanced wireless algorithms, we have already understood the purposes, goals, approaches of the two algorithms - PRKS(Physical-Ratio-K scheduling) and pktRT(Probabilistic Per-Packet Real-Time). In the next few weeks, we need to list out the parameters which will be used in the two algorithms and provide the mathematical formulas related to them. The method we are using during the stage of understanding the advanced algorithms is the Agile mode. Since the algorithms have multiple branches and we need to look through other papers to help us to understand the PRKS and pktRT algorithms, so we used the agile model to solve the problem.

2.2 Design Analysis

For the group which focuses on OpenWrt, we installed VirtualBox application on our computers and set up the network adaptor and SSH. And now we are on the testing stage. This work worked as expected since we **followed the instructions step by step**. Based on our observations, this is a

good start of the project, we should build the project step by step in order to reduce redundant time on checking previous mistakes.

On the other side, the group tried to understand the advanced wireless algorithms, we have understand the purposes, goals, approaches of the two algorithms - PRKS(Physical-Ratio-K scheduling) and pktRT(Probabilistic Per-Packet Real-Time). This is an understanding part of our project. This is just a summary of the algorithms we are going to work with. Based on our observations, we will spend plenty of time on digesting the core ideas of the algorithms since **none of us had previous experience** with the wireless networks. Our idea about how to solve the problem is to **do a detailed reading of the peripheral papers** like ONAMA which could help us to understand the core ideas in PRKS and pktRT.

2.3 Development Process

For the whole project of Open-Source Prototyping of Advanced Wireless Systems for Smart Agriculture and Connected Rural Communities, we are following the Agile approach during the development processes.(We implement the Agile approach not only on software developing but all of our development strategies)

We break the project into different stages, we developed a Gantt chart which listed detailed deadlines for each of our objectives to different stages. For instance, we set up deadlines for OpenWrt virtualization, Algorithms understanding, Prototype development(the deadlines are often set at the end of the week because we have a fixed meeting time on Monday morning every week). For each single task, we create a corresponding card on our trello and synchronize the task to trello every week. So, team members who take responsibility to their jobs can publish some links or descriptions on the card. Therefore, for our project we are using the Gantt chart and trello to sprints and tracks the development process.

As mentioned before, we are using Agile approach in our development processes. For each task, we have several stages. For instance, when we are virtualizing OpenWrt, we first find out the requirement like which version we should install, and then after planning out the details we start to develop it. Moreover, the testing stage, deploy stage, and review stage is essential for a single task. Not only for OpenWrt virtualization, we implement Agile approach on all of our tasks. This is the development process for each of our single tasks.

2.4 Design Plan

Use case of the OpenWrt system: we receive videos from monitors in rural farms on the system.

Use case of advanced 5G wireless algorithm: we eliminates the delay and decrease package loss rate by applying advanced 5G wireless algorithm in the prototype.

Use case of Gantt Chart: we follow the schedule on the gantt chart during the process of the project.

Use case of trello: we use trello application to list out the tasks needed to be done and tasks had done and the deadline for each task.

3. Statement of Work

3.1 Previous Work And Literature

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.2 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.3 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and to understand interdependence among tasks.

3.4 Possible Risks And Risk Management

Include any concerns or details that may slow or hinder your plan as it is now. These may include anything to do with costs, materials, equipment, knowledge of area, accuracy issues, etc.

3.5 Project Proposed Milestones and Evaluation Criteria

What are some key milestones in your proposed project? Consider developing task-wise milestones. What tests will your group perform to confirm it works?

3.6 Project Tracking Procedures

What will your group use to track progress throughout the course of this and next semester?

3.7 Expected Results and Validation

What is the desired outcome?

How will you confirm that your solutions work at a **High level**?

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

• A realistic, well-planned schedule is an essential component of every well-planned project

• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 3.3) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Completely compatible with an Agile development cycle if that's your thing

How would you plan for the project to be completed in two semesters? Represent with appropriate charts and tables or other means.

Make sure to include at least a couple paragraphs discussing the timeline and why it is being proposed. Include details that distinguish between design details for present project version and later stages of project.

4.2 Feasibility Assessment

Realistic projection of what the project will be. State foreseen challenges of the project.

4.3 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just "X" hours per week for the number of weeks that the task is active

4.4 Other Resource Requirements

Identify the other resources aside from financial, such as parts and materials that are required to conduct the project.

4.5 Financial Requirements

If relevant, include the total financial resources required to conduct the project.

5. Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library

Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

5.1 Interface Specifications

– Discuss any hardware/software interfacing that you are working on for testing your project

5.2 Hardware and software

– Indicate any hardware and/or software used in the testing phase

– Provide brief, simple introductions for each to explain the usefulness of each

5.3 Functional Testing

Examples include unit, integration, system, acceptance testing

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

• This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.