Project Plan V2

Open-Source Prototyping of 5G Wireless Systems for Smart Ag, Autonomous Vehicles and Beyond

sdmay19-04

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List of Definitions

AV (Autonomous Vehicle)

CPS (Cyber Physical Scheduling)

IoT (Internet of Things)

OAI (Open Air Interface)

PRK (Physical-Ratio-K)

SNR (Sound to Noise Ratio)

SUMO (Simulation of Urban Mobility)

TRaCI (Traffic Control Interface)

V2V (Vehicle to Vehicle)

VM (Virtual Machine)

Introductory Material

1.1 Acknowledgement

Professor Zhang Hongwei is our adviser, PhD student Yuwei Xie is our OAI expert resource, and we have total 6 people in our group, Anthony Benson, Jared Gorton, Hye-Sung Moon, Khanh Luu, Ted Miller, Jaime Zetina.

1.2 Problem Statement

Today's current network speeds that are available through 4G LTE are essential for the demand of data and communication the world has. The new development of smart IoT's has begun to demand more from 4G LTE and 4G LTE is quickly reaching it limit in its' ability to support the new wave of IoT's.

The development of 5G will allow the new world of smart IoT's to send, receive and access the data it needs at the time it needs it to operate at its full capacity. We are prototyping a 5G network to be able to deliver on this demand.

1.3 Operating Environment

The operating environment is ideally everywhere and anywhere IoT's can be found. IoT's to include fully autonomous devices such as autonomous vehicles (AV)s and autonomous agriculture tractors on the roads and farms every city. The network must work in every location from the most dense city to the ruralest of county sides with the same low latency and most importantly the highest predictable reliability.

In specific the applications that we are focusing are main efforts to are the ones that require real time data processing to make decisions as fast or faster than that of the human mind. The AVs will be our main focus, we must ensure their communication maintains the promised low latency and predictable reliability to make the split second decision making required for safe operation in every road condition in the world. Of course we must consider environments beyond our physical one. AVs will be operating under extremely congested areas of communication. The performance of the network will need to operatere is these environment and the implementation of CPS over OAI 5g simulation will deliver this.

1.4 Intended Users and Intended Uses

The intended users is everyone and (everything). Everyone that is now and will be using any kind of wireless communication to access smart IoT's. Everything that is itself a smart or autonomous device.In specific our efforts will cater to those who are within the AV industry to include AVs manufacturing companies and urban transportation planners who will be designing the urban traffic flow for AV dominated roads.

This application has the intended use as a high reliability, low latency 5G wireless network. Specific to our research these two requirements critical for the successful worldwide implementation of AVs. Although we will use 5G's the low latency and high reliability for our specific goal, there will be an infinite use for it in the future.

1.5 Assumptions and Limitations

We assume the autonomous vehicle and the IoT industry will grow exponentially, the importance of high speed, low latency, and predictable reliability network systems is emphasized. One of the most promising options is the 5G network. The 5G network will provide a data rate that is 20 times faster than that of the 4G network, in addition to this the error rate and latency will be near to zero. We are expecting that our simulation will fulfill the high reliability as well as low latency required to operate a successful V2V network.

Given the fact that we are designing a 5G network prototype, there is a practical limitation to fulfill the latency requirement which is less than 1ms. We have decided to improve the 4G (100ms) latency level as much as possible but put forth are main efforts to focus on reliability of our network.

1.6 Expected End Product and Other Deliverables

The expected end product is a simulation where each vehicle on the road is linked to our network and through the network to each other. During the up and down link to network, each vehicle will attempt to transmit and receive information. In a real world fashion this will cause interferences (uncertain or unpredictable) between vehicles. The algorithm that will implement in our simulation will overcome these interferences by CPS to increase the speed and reliability of the communication between vehicles.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The main objective of this project is to create a simulation of V2V network over OAI and SUMO which overcomes the interferences by CPS and PRK.

2.2 Functional Requirements

The main functional requirement for our simulation is:

The algorithm should be able to verify and overcome the interferences caused by multiple vehicles communicating in the same region.

To obtain the successful simulation , following specifications are required:

1. Vehicles' location
2. SUMO sample map: Ames
3. Setting the speed limits on the road:
    a) Small city street: 25 mph
    b) On I-35: 70 mph
4. Desired communication range: 1 - 150m
5. Desired broadcast reliability: 90%
6. Transmission rate: 6Mbps
7. Transmission power: 6dB absence of interferences
8. SNR: 90% of reliability of 150 meters length
9. Size of data packet: each data packet is 1500 bytes

Figure 1: Map of Ames IA, USA

2.4 Previous Work And Literature

Our advisor, Prof. Zhang, has already done research on V2V communication with CPS. In his work, the simulation was ran over SUMO and ns-3. ns-3 is widely used network simulator. During this simulation, he experimentally analyzed the behavior of CPS by integrating high fidelity ns-3-based wireless network simulation and SUMO-based vehicle dynamics simulation. Based on this research, we are going to make a simulation over different communication simulator OAI. The advantage of using OAI can implements the full the full protocol stack to run on a real execution environment respecting frame timing constraints. As a result, it is a more realistic platform(even in simulation).

2.5 Proposed Design

Our proposed simulation will be based on OAI. For V2V wireless channels, we implement in OAI a channel model based on real-world. For vehicle mobility dynamics, we use the SUMO simulator that simulates vehicle traffic flow dynamics at high-fidelity based on real-world road and traffic conditions of Ames IA, USA. To integrate this two system, we will use TraCI(Traffic Control Interface) of SUMO.

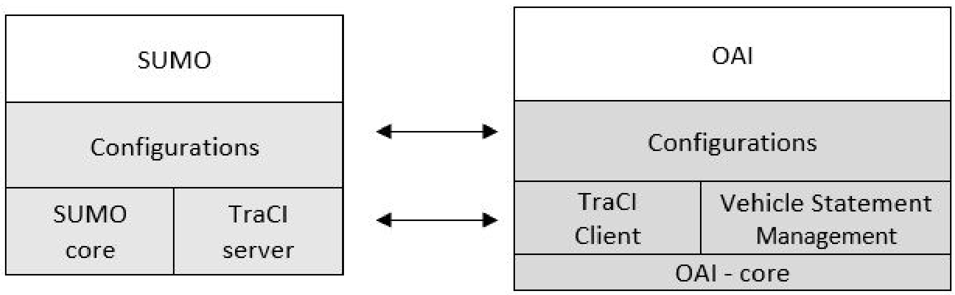

Figure 2: Integration of SUMO with OAI

For designing the network system over OAI, we will implement the Cyber Physical Scheduling, which can overcome the interferences between V2V communication in crowded urban area.

2.6 Technology Considerations

Both SUMO and OAI are based on LINUX system, we will run these program over virtual machine 'ubuntu'. One issue is that the version of ubuntu has to be a particular version of ubuntu. This is offset a bit though by being able to share the latest versions of the virtual machines through the group. The alternative to using virtual machines is partitioning our computers. The main problem with this method is that if one person makes progress the whole group still won't. There really isn't a good viable alternative to SUMO. We have resources about SUMO and OAI working together which makes it the best option..

2.7 Safety Considerations

Most of the project is software applications so there are little to no safety considerations needed for most of the project. The only thing would be that if we get far enough to setup the network systems on AVs. In which case there will be possible errors cannot be detected during the simulation.

2.8 Task Approach

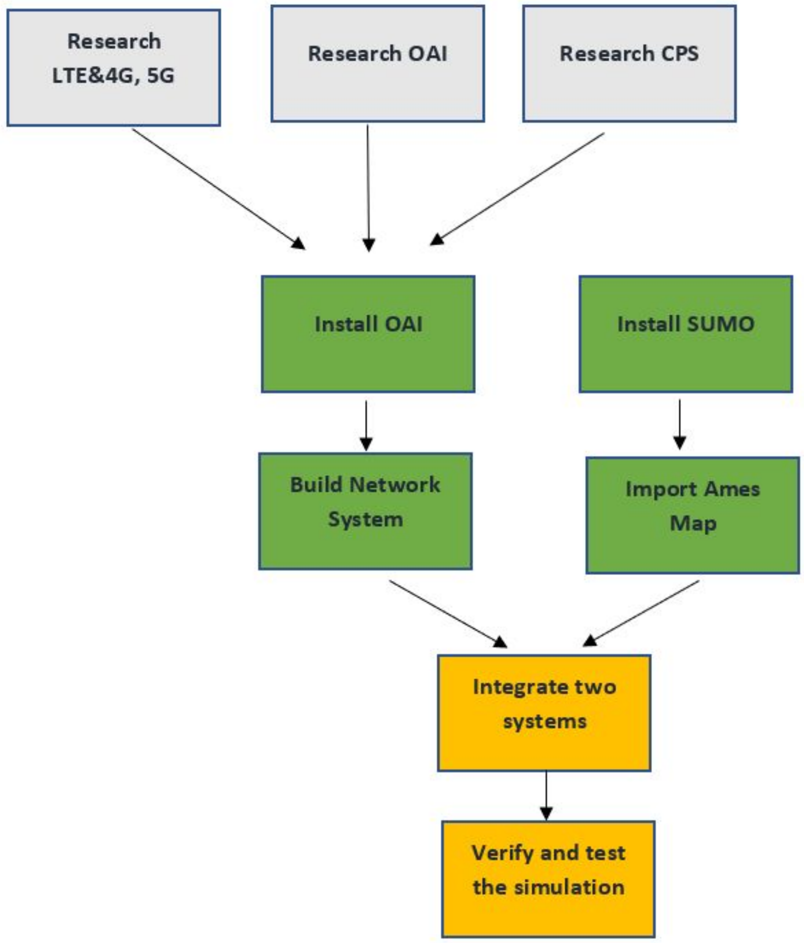

Figure 3: Task Approach Overview

The first part of the project will mainly be focused on research. The research will be broken into two different categories in-order to save time. One category will by CPS and the other will be OAI. CPS will involve more research and will focus on developing a CPS algorithm. OAI will have less of a focus on research and will mainly be getting the software up and running. After we acknowledge CPS and regarding material, we will install the OAI and SUMO. We will build the CPS algorithm over OAI simulation and import the Ames map over SUMO. When both simulations are done, we will integrate these two systems and test it.

2.9 Possible Risks And Risk Management

The main hindrance to the project will be the knowledge that is needed for the project. To solve this issue the group has jumped into research on the matter.

Another risk will be compatibility of our PCs and simulation programs. OAI and SUMO need unique and specific requirements, there is a possibility to have few errors when we are running them.

2.10 Project Proposed Milestones and Evaluation Criteria

The first main milestone of the project is finishing our CPS research materials. Also in the first milestone will be getting OAI up and running. The second milestone will be developing a CPS algorithm over OAI. CPS algorithm will be put into OAI for our third milestone. This milestone will be integrated with SUMO. This will also act as testing for the second milestone as well. After integration, we will test the simulation and troubleshooting the unforeseen errors.

2.12 Expected Results and Validation

The desired outcome for the project is a high reliability of V2V communication with CPS algorithm. To verify the algorithm and its reliability, we will implement the CPS algorithm over OAI and integrate with SUMO for vehicle dynamics.

2.13 Test Plan

We will test the two items over simulation. Two items are following:

1. **Reliability:**

    The reliability is the essential part of V2V communication. Conventional network systems have limitation of overcoming the interferences between vehicles. Theoretically, we can obtain high reliability over CPS algorithm, and we will test through simulation with OAI and SUMO.

    Test Method: Test will be implemented by sending the certain number of data packets. Tx/Rx * 100 will be the reliability.

    Expected Results: We expect that we can obtain more than 90% reliability over simulation.

2. **Delay:**

   Delay is the other factor that we need to consider for simulations. In fast moving vehicles, a tiny amount of time delay can be a tremendous difference.

   Test Method: We will timestamp events and then calculate the time difference between events.

   Expected Results: Current 4G network has a latency of 50ms. Although, it is not good enough for AVs, due to practical limitation, we expected that delay will be same level as 4G network. In crowded region, we expected more than 50ms.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

Assignment	9/3 - 10/12	10/13 - 10/26	10/27 - 12/14	1/7 - 1/31	2/1 - 2/15	2/16 - 3/30	4/1 - 5/1
Read 4G LTE Advance Pro and The Road to 5G							
Research Unified Cellular Scheduling							
Research Cyber Physical Scheduling							
Research PRK paper							
Instialling OAI							
Verify the OAI program on Linux OS							
Installing SUMO							
Verify SUMO program on Linux OS							
Build Network System on OAI							
Build Sample map of Ames on SUMO							
Integrate OAI with SUMO							
Verify the simulation							
Test the simulation to meet the requirements							
Trobuleshooting the simulation							
Validate and finalize the simulation							

Table 1: Timeline of proposed work schedules

Due to our particular situation for our project, we spend most of time researching about the 5G network and regarding materials that we required.

First half of the Fall 2018 semester will be assigned for the researching about LTE and conceptual 5G and regarding materials. Second half of the Fall 2018 semester, we are going to install the OAI and SUMO on Linux based system. These two programs have very specific requirements to run, we need to adjust our personal laptop. To acquire Linux based system, we used 'ubuntu' virtual machine. First half of the Spring 2019 semester, we will build and test the OAI network system and build the map of Ames over SUMO, and validate the systems. Second half of the Spring 2019 semester, we will integrate the OAI and SUMO and test the simulation to meet the requirements.

3.2 Feasibility Assessment

Realistically we have the necessary information to fully implement the CPS algorithm over the open source prototyping platform creating a 5G prototype network. The steps that are outlined in this project plan demonstrate a step by step approach to achieve this goal. Our time line is set with realistic milestones that are within our capability of completing. We have planned and focused deadlines for our progress. Hardware resources that are required to complete this project are our laptops to fully implement simulations through Ubuntu in conjunction with sumo for real time data analysis of V2V network communication. Information resources that are available for our project are published works regarding 5G principles, CPS, PRKs, and future visions of the network. This includes but is not limited to paper listed in the references. At this time we see no requirements for funds. We have scheduled weekly meetings to allot time to ensure our milestones are being meet and any issues are being discussed and resolved.

3.3 Personnel Effort Requirements

Task	Description	Estimated Time(hours)
Read 4G LTE and 5G	Acknowledge the conventional communication system and the future 5G concept.	100
Read PRK and CPS papers	CPS is the key algorithm that we are going to implement, and CPS is based on PRK.	50
Installing OAI and SUMO	These two programs are key programs to run the simulation. We will run these program over virtual machine 'ubuntu'.	80
Build the network system over OAI	Building CPS algorithm over OAI.	120
Build sample map over SUMO	Import the Ames map on SUMO.	60
Integrate OAI with SUMO	For vehicle dynamic, we will integrate SUMO with OAI.	150
Test and Verify the Simulation	Finalize the simulation and test to meet the requirements.	60

Table 2: Task-by-task basis timeline

3.4 Other Resource Requirements

We will run SUMO and OAI over LINUX OS. We do not have any linux based computer, so we will run these program over virtual machine. We need to install 'ubuntu' which is open-source virtual machine.

3.5 Financial Requirements

Item	Description	Budget ($)
OAI	Network simulator: Open Source SW.	0
SUMO	Simulation program for urban mobility: Open Source SW.	0
LINUX OS	OS: We will use virtual machine 'ubuntu': Open Source SW.	0
PC	We are going to use our own laptop to make a simulation.	0

Table 3: Budget

Since our project is simulating the algorithm and required SWs are all open-source, total budget would be $0.

4 Closure Materials

4.1 Conclusion

As a group we have been working hard towards finishing our project. We have researched the basic necessary information for the project. This includes reading several research papers and books. Also we have worked on getting the software OAI running. OAI has proved to be difficult because of how specific its requirements are. Getting OAI up and running with our CPS algorithm is one of the big goals for the project. Another goal is to get it running in the simulation environment SUMO. To succeed in these goals we have broken into two groups and are working on the CPS algorithm and OAI separately to begin with. We will then come back together and get both working together to test in SUMO.

4.2 References

[1] Dahlman, E., Parkvall, S., & Sköld, J. (2016). *4G, LTE-Advanced Pro and the Road to 5G*. Amsterdam: Elsevier.

[2] OpenAirtInterface. The OpenAirInterface Software Alliance (OSA) is a non-profit consortium fostering a community of industrial as well as research contributors for open source software and hardware development for the core network (EPC), access network and user equipment (EUTRAN) of 3GPP cellular networks.

[3] Simulation of Urban Mobility. SUMO is an open source, highly portable, microscopic and continuous road traffic simulation package designed to handle large road networks. It is mainly developed by employees of the Institute of Transportation Systems at the German Aerospace Center. SUMO is open source, licensed under the GPL.

[5] Woo, A. (2018). *Evaluation of Efficient Link Reliability Estimators for Low-Power Wireless Networks*. [online] Digitalassets.lib.berkeley.edu. Available at: http://digitalassets.lib.berkeley.edu/techreports/ucb/text/CSD-03-1270.pdf [Accessed 24 Oct. 2018].

[6] Ubuntu. Ubuntu is a complete Linux operating system, freely available with both community and professional support.

[7] Zhang, H. (2018). *Scheduling with Predictable Link Reliability for Wireless Networked Control*. [online] Ece.iastate.edu. Available at: https://www.ece.iastate.edu/~hongwei/group/publications/PRKS-TWC.pdf [Accessed 24 Oct. 2018].

[8] Zhang, H. (2018). Cyber-Physical Scheduling for Predictable Reliability of Inter-Vehicle Communications. [online] Ece.iastate.edu. Available at: http://www.ece.iastate.edu/~hongwei/group/publications/CPS-IOTDI18.pdf [Accessed 24 Oct. 2018]

[9] Zhang, H. (2018). *Link Estimation and Routing in Sensor Network Backbones: Beacon-based or Data-driven?*. [online] Cs.wayne.edu. Available at: http://www.cs.wayne.edu/%7Ehzhang/group/publications/LOF-TMC.pdf [Accessed 24 Oct. 2018].