Semi-Annual Progress Report

TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

Project Number and Title: *4.3. Towards Quantitative Cybersecurity Risk Assessment in Transportation Infrastructure*
Research Area: *Thrust 4 Connectivity for enhanced asset and performance management*
PI: *Dr. Song Han, Assistant Professor, Department of Computer Science and Engineering, University of Connecticut*
Reporting Period: *April 1st, 2019 – September 30th, 2019*
Date: *September 30th, 2019*

Overview:

Activities: During the reporting period, the research team at UConn led by PI Han has continued to study the security and privacy issues in vehicle-to-everything (V2X) communication. The research team performed a comprehensive literature study and summarized the key research topics in this context. These topics include but are not limited to key and identity management, privacy preserving, tamper proof device and decision on cryptosystem, vehicle intrusion, multi-function detection and data consistency, secure communication protocol, secure positioning and secure user interface. Based on this literature study, the research team decided to focus on the first two topics and then extend the study to the other topics when the project progresses. The research team proposes to develop a security baseline architecture for V2X communication infrastructure focusing on communication security and baseline privacy enhancing technology. To make the proposed security architecture practical to future DoT use, we will employ standardized cryptographic primitives, make it easy to implement with low overhead and adaptable protection. For the key and identity management, we propose to employ a certificate-based security architecture that employs hierarchical certificate authority (CA) to provide/renew/revoke certificate and provide background connection to distributed CAs. The research team is working towards the design of a security architecture (see Figure 1) that is composed of the following key modules: in car security module, secure communication module, identification and trust management module, and privacy management module. Those modules, based on their functions, will be deployed on different physical entities, including vehicles, road-side unit (RSU) and service infrastructure accordingly (see Figure 2). For the privacy preserving purpose, the V2X communication should be oblivious. It should not make it easier to identify or track vehicles and should conform to future privacy directives. We propose to design privacy-enhancement mechanisms using resolvable pseudonyms. Based on this mechanism, each vehicle will be equipped with multiple pseudonyms. These pseudonyms will be alternated over time and space. Individual vehicles will sign message with the private key corresponding to pseudonym. The vehicle will also append the current pseudonym to signed message so that the recipient will be able to verify the messages.

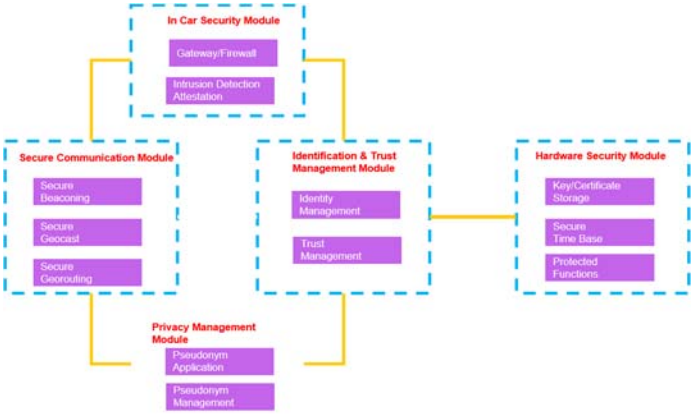

Figure 1. Building blocks of the V2X security architecture

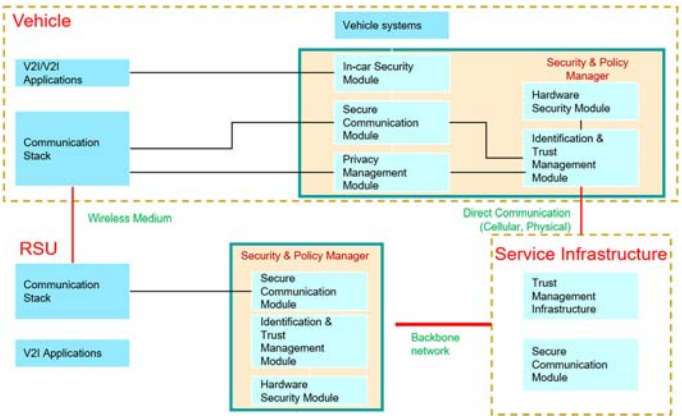

Figure 2. The deployment of the V2X security architecture

During the reporting period, the research team also studies the simulation tool and potential hardware testbed setup for performance evaluation on the proposed secure V2X secure communication framework. The research team has decided to conduct the V2X simulation through the integration of SUMO (Simulation of Urban MObility) and NS-3. SUMO is an open source, highly portable, and continuous road traffic simulation package designed to handle large road networks. It is particularly suitable for this project due to its microscopic nature and its strength in simulating V2X applications. To simulate the V2X communication, the network simulator NS-3 will be integrated with SUMO through the iCS open source system to provide the synchronization and message exchange between the two simulators.
To lay the foundation for real-world demonstrations of the envisioned technologies, the research team is under planning to develop F1/10 autonomous car prototype to conduct in situ driving experiments. Such experiments are necessary for two

reasons: 1) to collect real-world data on signal propagation, interference, and cyber/physical traffic patterns that can be used to build and validate larger-scale models using SUMO, and 2) to transition the proposed V2X security and privacy framework into prototype demonstrations. Based on the current planning, the F1/10 autonomous car prototype will be built on the Traxxas Slash model car, and consists of the following major hardware components: 1) NVIDIA Jetson Tx2 embedded AI computing platform, 2) LIDAR sensor to measure the distance to surrounding objects, and 3) Zed stereo camera to create the depth image by using dual cameras. This hardware platform also has the following software stacks deployed: 1) NVIDIA L4T 28.1 package, 2) LitmusRT framework which provides better real-time scheduling capability compared to vanilla Linux kernel scheduler, 3) ROS framework and the autonomous control application built on top of it. The research team plans to set up a three-lane circular track in the basement of the UConn ITE building to emulate mutli-lane highway scenarios. 802.11p compatible wireless modules will be installed on these cars to support V2V communications and 802.11p compatible wireless access points will be deployed around the testbed to serve as RSUs to support V2I communications. The proposed security/privacy mechanisms will be implemented on individual cars/RSUs.

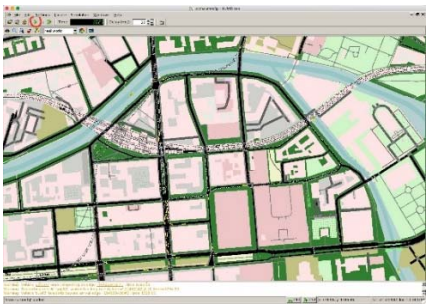

Fig. 3. SUMO simulation tool

Fig. 4. F1/10 car prototype

Fig. 5. AV to be procured

Fig. 6. UConn test facility

PI Han and Prof. Jonathan Rubin and Kathryn Ballingall from University of Maine have continued to exchange their research progress during the reporting period on V2X related research topics. Two brainstorming meeting have been scheduled to disucss ideas for potential collaborative proposal and data sharing. PI Han has also formed a team at UConn (including 24 faculty from 7 departments across 3 schools at UCONN) to participate in the internal competition for the NSF MRI program. The proposal entitled: “The Acquisition of Autonomous Vehicles (AVs) to Advance AV Research under Challenging Topography and Weather Conditions” aims to procure two AVs and requisite software and support to operate these vehicles. These vehicles will be primarily used to conduct critical technical AV research, including V2X communication, resilient control, cybersecurity, machine learning and decision making that is desperately needed to facilitate the integration of AVs into our existing transportation system. These vehicles will also be instrumental in outreach and education activities in the Northeast, while allowing for targeted research on public perception, human behavioral, and human-machine interaction research. Use, storage and maintenance of these vehicles will be managed by the Connecticut Transportation Institute (CTI) during and after the proposed project period, and UConn will establish a test facility on its Depot Campus to provide a combination of ideal and deteriorated roadway conditions, signage and physical infrastructure that these AVs will encounter in the real world.

Accomplishments: the accomplishments of this project during the report period include two paper drafts ready for submission. One NSF pre-proposal has also been prepared and are currently under submission.

[1] Gang Wang, Song Han, “Security Issues in Low-Power Wireless Networks: A Stack View”, to be submitted to IEEE Communication Surveys & Tutorials.

[2] Areej Althubaity, Tao Gong, Mark Nixon, Raymond Kim Kwang Choo, Reda Ammar, Song Han, "Specification-based Detection of Rank-related Attacks in RPL-based Resource-Constrained Real-Time Wireless Networks", revised and to be submitted to the International Conference on Information Processing in Sensor Networks (IPSN).

[3] NSF MRI: The Acquisition of Autonomous Vehicles (AVs) to Advance AV Research under Challenging Topography and Weather Conditions, under submission for UConn internal competition, $1,000,000, 7/1/2020 – 6/31/2024.

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Training/professional development opportunities: During the reporting period, three PhD students have participated in this research project. One PhD student, Mr. Gang Wang, mainly focuses on the literature survey of the cybersecurity and privacy issues in V2X communication infrastructure, and the design of security baseline architecture and privacy-preserving mechanism; the other PhD student, Ms. Areej Althubaity, mainly focuses on the IDS design for 6TiSCH wireless networks to identify Rank-related attacks. Based on the feedback received from IEEE Transactions on Industrial Informatics (TII) reviewers, she has significantly improved the IDS methodology design and has evaluated the new designs under more comprehensive network settings. A new PhD student, Jiachen Wang, has also joined PI Han's research lab since August 23rd, 2019. He is now working with Gang on the cybersecurity issues in V2X infrastructure.

Dissemination of research results: PI Han attended and gave a presentation at the first Annual Conference for US DOT Region 1 UTC-Transportation Infrastructure Durability Center (TIDC) held at University of Maine during June 6-7 to describe his research work in this project. PI Han also had a constructive meeting with Connecticut DOT leadership and engineers to discuss research collaborations on addressing IT infrastructure security and privacy issues that are of the interest of CTDOT. Point of contact has been identified.

Participants and Collaborators:

PI Song Han, Assistant Professor, Department of Computer Science and Engineering, University of Connecticut

Student Researcher: Jiachen Wang, PhD student, CSE@UConn, secure vehicle-to-everything (V2X) communication
Student Researcher: Gang Wang, PhD student, CSE@UConn, secure low-power wireless network systems design
Student Researcher: Areej Althubaity, PhD student, CSE@UConn, intrusion detection system design for 6TiSCH network
Potential Collaborator: Mr. Bing Ai, Research Engineer, Ford, studies of safety issues in autonomous vehicles

Changes:

No significant changes on the scope and methodology design in the project. Based on extensive literature study, the focused study subjects have been narrowed down from general transportation infrastructure to low-power wireless network infrastructure for structural monitoring and V2X communication infrastructures due to their importance and potential great impact to the US and State DOT and the whole transportation industry. Between these two directions, a higher priority has been given to the V2X communication infrastructure due to its increasing popularity and more challenging research problems whose solutions are still unknown to the research community. Thus this report mainly focus on the security and privacy issues in V2X communication infrastructure.

Planned Activities:

Based on the study conducted in this reporting period, we are planning the following R&D activities in the project:

- We plan to continue the design of the security baseline architecture, the proposed privacy-preserving mechanisms, and the implementation and performance evaluation of the proposed model and methods in both simulation-based (SUMO + NS3 simulators) experiments and testbed-based experiments.
- PI Han plans to visit his collaborator, Mr. Bing Ai, at Ford Motor Company to present his previous and ongoing work in the designs of secure and real-time network fabric for cyber-physical systems and to discuss and understand better the safety issues that Ford is experiencing now in the designs of autonomous vehicles.
- PI Han will continue the conversation with Prof. Jonathan Rubin and Kathryn Ballingall from University of Maine to understand better the cybersecurity issues in the context of smart and connected bridge, and work on potential research problems that both UConn and U of Maine have mutual research and development interests.
- PI Han will start recruiting undergraduate students at UConn to join the PI's research lab to work with the PhD student researchers on R&D tasks related to this project. These undergraduate students will work with the PI in the form of independent studies in the Fall semester of 2019 or Spring semester of 2020.