An Open Platform for Research and Development in Intelligent Transportation Systems

Albin Severinson, rendits.com
Gothenburg, Sweden

***Abstract*—The Rendits Vehicle-to-Anything (V2X) Router is a platform for research and development in intelligent transportation systems. It supports 802.11p wireless communication and the European Telecommunications Standards Institute ITS-G5 standard. It is built from the ground up to be extensible and easily modifiable. For example, it is easy to modify or replace parts of the software stack, and to transmit customized messages. We believe that openness is critical in research and development. Hence, the Router runs a software stack that is open source under the Apache 2.0 license, i.e., you are given access to the code freely and are given the option to open source your contributions or not. The Router is based on a powerful single board computer and has been used successfully in several projects. This document is meant to help you decide if the Rendits V2X Router is the right product for you, and how it can be integrated in your project.**

I. Introduction

Intelligent transportation systems (ITS) have shown potential in a wide range of scenarios. For many of these scenarios communication is a key component. For example, vehicles may need to communicate with other vehicles, roadside units, or pedestrians. This is often referred to as vehicle-to-anything (V2X) communication. There has recently been significant interest in researching V2X communication and in developing applications that make use of V2X communication.

There previously existed two paths for achieving V2X communication. The first path was to buy products from the established companies. These products are robust and well-tested. However, they are also inflexible and very expensive. It is often difficult or impossible to make the modifications needed for research and development. We needed something else for our own research. The second path was to build it yourself from scratch. This path yields a system that is very flexible, but also one that is untested and potentially not standards-compliant. Furthermore, it requires spending a significant time on things not directly related to the project at hand. We would prefer spending our time on research rather than on compiling the Linux kernel.

The Rendits V2X router represents a third path. We took the second path because no-one would sell us the product we needed. Now we make the results available to you. Specifically, the Router is a collection of open source software components running on standardized hardware that facilitates 802.11p wireless communication compliant with the ITS-G5 standard issued by the European Telecommunications Standards Institute (ETSI) [1]. The Router is compatible with Kapsch and Cohda modems. We developed the router with two scenarios in mind. The first is one where V2X communication is a component of a larger application. The Router can be added to an existing system and will easily interface with other systems, including those built in Matlab/Simulink. It allows sending messages compliant with the ITS-G5 standard as well as messages containing arbitrary data, e.g., for novel applications not considered in ITS-G5. The second scenario is one where research on V2X communication itself is the goal. Since the code is open source you can easily see how everything works. It is also easy to modify or replace any component of the software stack. We think the router may be useful to you if you fit in one of these categories.

This work was presented in part in “Design and Experimental Validation of a Cooperative Driving Control Architecture for the Grand Cooperative Driving Challenge 2016”, published in IEEE Transactions on Intelligent Transportation Systems in April 2018 (volume 19, issue 4, pages 1290-1301). Initial development was conducted with support of the Department of Electrical Engineering, Chalmers University of Technology, SE-41296 Gothenburg, Sweden.

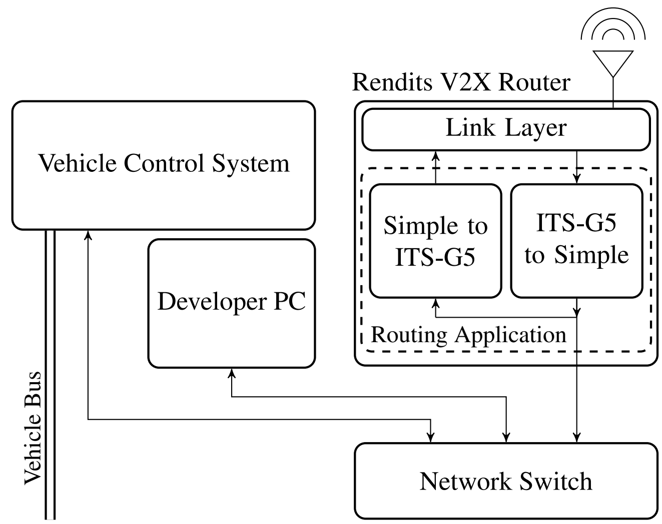

Fig. 1. System overview

We first give a brief description of the router. Next, we present two cases where the Router has been used previously. Finally, we give performance metrics.

II. Rendits V2X Router

The Rendits V2X Router is designed with the system architecture shown in Fig. 1 in mind. In particular, we assume

Fig. 2. Rendits V2X Router. From left to right: SMA connector for roof-mounted antennae, serial connector, three one-gigabit ethernet connections, two USB ports, and a 12V power jack.

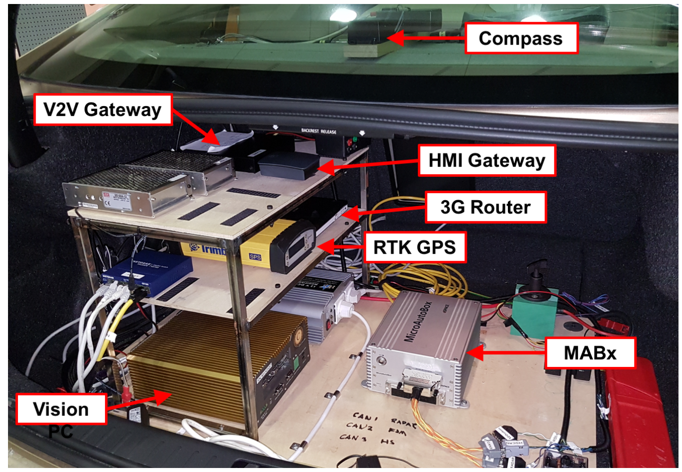

Fig. 3. Hardware installation used by the Chalmers Car team in the GCDC 2016 competition. The Rendits router is marked with “V2V Gateway” and the veehicle control system is marked with “MABx”.’Photo and editing by Robert Hult.

that there is a local network connecting an arbitrary number of devices, with each device running part of an ITS application. We refer to the device connected to the vehicle, for example via the CAN bus, as the “vehicle control system”, and the computer that the developer is working from as the “developer PC”. The router is added to the network using a wired network connection. It communicates with other devices on the wired network via UDP messages and wirelessly with other devices that supports 802.11p. The Router acts as a gateway that transmits messages sent from the vehicle control system wirelessly and forwards incoming wireless messages to the vehicle control system. Note that it is also possible to run applications on the router itself. See Fig. 2 for a picture of the router.

A key feature of the Rendits router is its simplified message set that allows devices to send and receive ITS-G5 messages without having to deal with its complexities. The application responsible for converting proper ITS-G5 messages to their corresponding simple messages is referred to as the routing application in Fig. 1. The routing application is built on top the of an open source Geonetworking library [2].

The router hardware platform is the PC Engines apu2c4 x86 single board computer [1]. Hardware documentation can be found at [2]. The network card included is based on the AR9280 chipset [3].

III. Case Study: GCDC

In the Grand Cooperative Driving Challenge (GCDC) [3], university teams in cooperation with auto makers compete in building a vehicle that can communicate with other vehicles to perform manoeuvres, such as lane merging, autonomously. Successfully completing the scenarios requires accurately tracking the position of ones own vehicle and that of other vehicles, and communication intentions to other vehicles. This is achieved via a combination of sensors and V2X communication.

For the Chalmers car team the vehicle control system and higher level logic control was implemented in Matlab/Simulink running on a dSpace Micro Autobox [4]. The Autobox had access to the vehicle sensors and could control the vehicle via its CAN bus. Vehicle locations and intentions were communicated using a modified version of the ITS-G5 standard. The control system communicated with the Rendits Router using its simplified message set, which can easily be implemented in Simulink. This allowed access to ITS-G5 communication from the control system. The setup used is shown in Fig. 3.

During the challenge several teams used the hardware platform and software included with the Rendits V2X Router. About 10 vehicles, each transmitting 25 messages per second, participated in the challenge scenarios with no throughout or latency issues.

IV. Case Study: Autonomous Intersection

In the autonomous intersection project, researchers at Chalmers University of Technology, Sweden, used V2X communication to optimize intersection throughout. In this project, three vehicles start at the same distance from three-way intersection. As the vehicles approach the intersection, they communicate their speed, location, and intention to a roadside unit. The roadside unit computes the optimal order for the vehicles to enter the intersection by solving an optimization problem and sends instructions back to each of the vehicles. The vehicles and the roadside unit was equipped with a Rendits V2X Router and communicated via a custom message set. More information, including a short video, is available at

[1] https://www.pcengines.ch/apu2c4.htm
[2] https://www.pcengines.ch/pdf/apu2.pdf
[3] https://www.pcengines.ch/wle200nx.htm

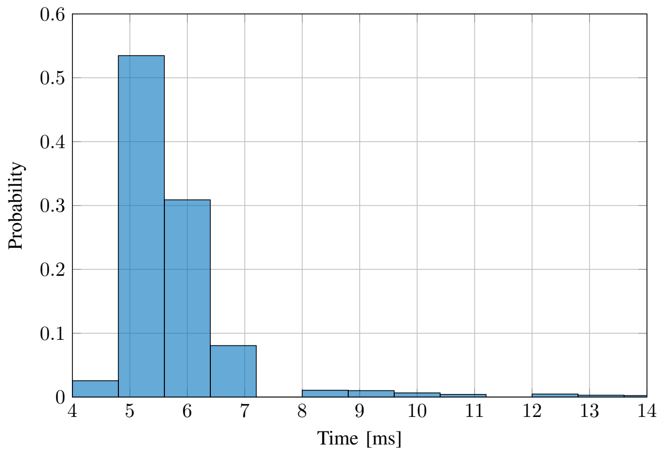

Fig. 4. Estimate of the communication round trip time distribution based on experimental data.

the Chalmers webpage [4].

V. ITS-G5

ITS-G5 is a communication standard by ETSI for use in ITS. It specifies all layers of the communication stack. For example, the standard mandates that 802.11p wireless access technology should be used, how routing is performed, and how the standardized messages should be formatted. In particular ITS-G5 specifies the cooperative awareness message (CAM) for transmitting dynamic information such as speed and location, and the decentralized environmental notification message (DENM) for transmitting information about specific events, such as road works warnings. An overview of CAM and DENM is given in [5]. The full ITS-G5 specification is available at [1].

In addition to CAN and DENM there is the iGAME cooperative lane change message (iCLCM) [5]. This message was proposed within the European iGAME project to facilitate more complex manoeuvres, such as platooning and lane changing, for which CAM and DENM is not enough.

The Router supports all of CAM, DENM, iCLCM. Furthermore, the Router makes it easy to send custom messages that include information not part of the standardized messages.

VI. Performance

In this section we provide some performance statistics of the router. The router is designed to operate at a range of 200 meters, but has been used at a range of up to 500 meters with a roof-mounted Mobilemark ECOM9-5500 antennae.

We measure the latency by equipping two routers with antennae, connecting them to a laptop through a 1 Gbps switch, and measuring the round trip time. Specifically, one router receives messages from the laptop via ethernet and transmits them over the air, while the other router receives these messages and forwards them back the laptop via ethernet. The laptop measures the latency by comparing a timestamp included in the message with the current time. The laptop generates 500 CAM messages per second. The measurements thus include the delay incurred by the laptop network stack, and the switch processing time. The antennae were placed about 1 meter apart and the resulting latency distribution is shown in Fig. 4.

[4]https://www.chalmers.se/en/areas-of-advance/Transport/news/Pages/Self-driving-cars-negotiating-their-way-through-the-intersection.aspx

VII. Conclusion

Rendits was founded to promote research and development in ITS. Our interest is in empowering our users and we hope that the Router will be a useful tool in your work. We will gladly help you get started and adapt the Router to your needs. Please do not hesitate to contact us at albin@rendits.com if you have any questions.

References

[1] ETSI, "ITS-G5 Standards Documents," http://www.etsi.org/technologies-clusters/technologies/automotive-intelligent-transport, April 2017.

[2] A. Voronov, J. De Jongh, D. Heuven, and A. Severinson, "Implementation of ETSI ITS G5 GeoNetworking stack, in Java: CAM-DENM / ASN.1 PER / BTP / GeoNetworking," Jun. 2016. [Online]. Available: https://doi.org/10.5281/zenodo.55650

[3] GCDC, "The Grand Cooperative Driving Challenge," June 2016. [Online]. Available: http://gcdc.net/en/

[4] R. Hult, F. E. Sancar, M. Jalalmaab, A. Vijayan, A. Severinson, M. D. Vaio, P. Falcone, B. Fidan, and S. Santini, "Design and experimental validation of a cooperative driving control architecture for the grand cooperative driving challenge 2016," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 4, pp. 1290–1301, Apr. 2018.

[5] GCDC, "Message Set," http://www.gcdc.net/images/doc/D3.2.Proposal.for.extended.message.set.for.supervised.automated.driving.pdf, June 2016.