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AIM reference track - test site for V2X communication systems and cooperative ITS services

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Abstract: Cooperative intelligent transport systems (C-ITS) based on Vehicle2X (V2X) communication are currently under development in the automotive industry and regarded to be in mass-production in the near future. In order to develop and test cooperative ITS services, the Institute of Transportation Systems of the German Aerospace Center (DLR) operates a large-scale test site in the city of Braunschweig, Germany. This research infrastructure facilitates test activities, measurements as well as evaluation activities for C-ITS in a real-life environment.

1 Introduction

The AIM Reference Track is part of the Application Platform for Intelligent Mobility (AIM). For further information reference is made to (Schnieder & Lemmer, 2012, 2014). One of the major goals of AIM is to perform research on the transport system of road traffic in a real-life environment. Therefore, several installations have been done in the city of Braunschweig, which is the second-largest city in the state of Lower Saxony. The AIM Reference Track was designed to support the development and test cooperative intelligent transport systems (C-ITS), such as advanced driver assistance systems (ADAS) or services at the road side infrastructure. The infrastructure of the test site focusses on Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication, or summarized as Vehicle-to-X (V2X) communication. The Application Platform for Intelligent Mobility (AIM) is a combination of large-scale research facilities operated by the Institute of Transportation Systems of the German Aerospace Center (DLR). The

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implementation of AIM has been funded with more than 15 million Euro by the Helmholtz Association of German Research Centers and by the Lower Saxony state government with budget of the European Union from the European Regional Development Fund (EFRE).

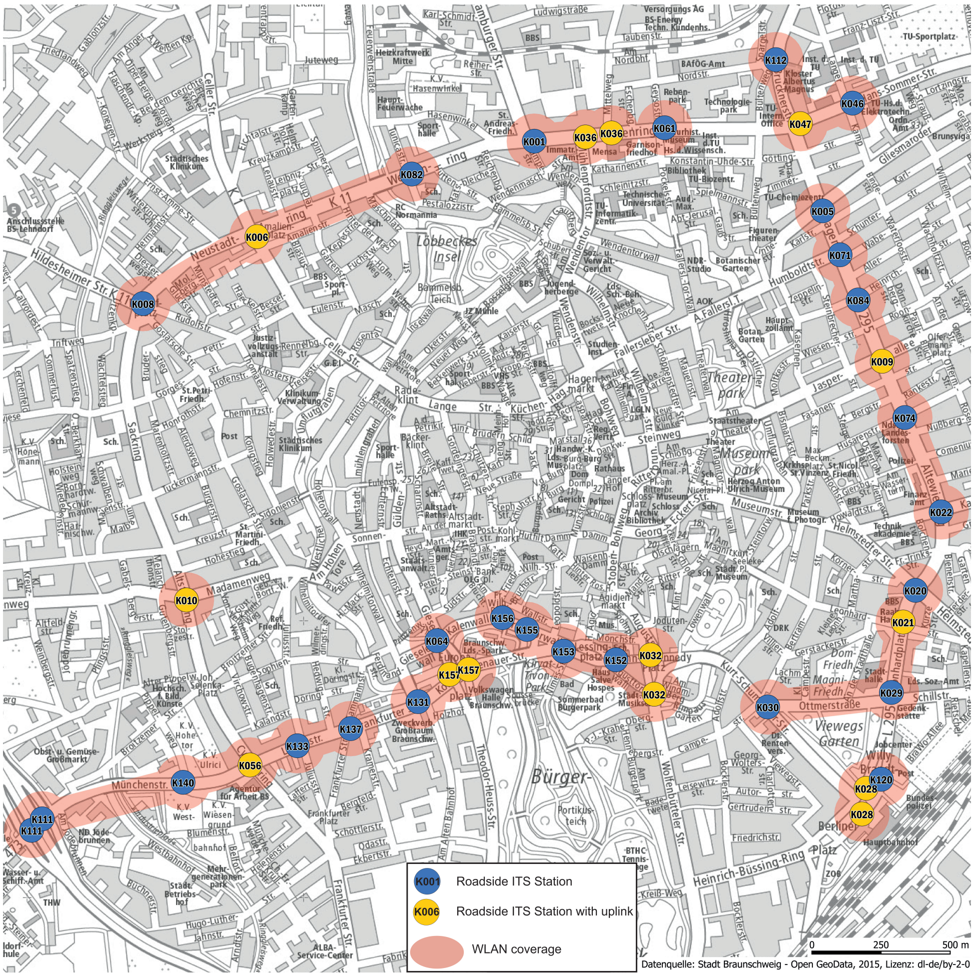

Figure 1: Map of the AIM Reference Track with RIS locations.

2 Technical Description

The technical set-up of the AIM Reference Track includes both decentralized equipment in the public road space (see section 2.1) as well as centralized equipment at the DLR campus (see section 2.2).

2.1 ITS Stations

The AIM Reference Track consists of so-called "Roadside ITS stations " (RIS) that are connected to the existing traffic light systems (Frankiewicz et al., 2012) Figure 2 depicts the functional architecture of the RIS. The existing traffic light controllers owned and operated by the City of Braunschweig are connected by a dedicated non-reactive interface that allows one-way communication between the traffic light controller and the DLR systems. The interface and the software on the traffic light controller ensure that there is no interference between the research systems and the traffic light systems that could negatively affect traffic safety. Any interaction between the traffic light controller and the RIS must be individually secured and revised by the road operator. Next to the traffic light interface, there is an Application Unit (AU), whose main task is to process for example information on the traffic light's state or sensor data, to handle message communication and to run project-specific applications. The Communication

Control Unit (CCU) handles the V2X communication to the vehicles according to the recent European standard (ITS-G5) and/or to project specific requirements. For time synchronization, the CCU runs a local time server and is therefore connected to a regular GPS receiver. Additionally, sensors can be connected to the AU, according to project or users requirements. For example, radar sensors are mounted at specific locations. These sensors enable traffic monitoring, counting and classification of vehicles, speed monitoring etc.

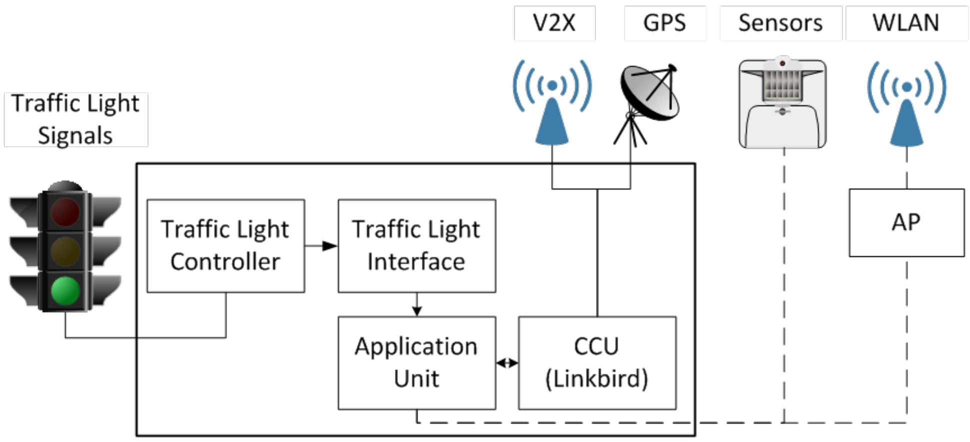

Figure 2: Architecture of a C-ITS roadside station.

Each RIS is equipped with a Wireless LAN Access Point (AP) that enables the distribution of information using regular WLAN (IEEE 802.11b/g/n at a frequency of 2.4 GHz) components, for example to smartphones. Furthermore, neighbor RIS are interconnected using IEEE 802.11a WLAN mesh network at a frequency of 5 GHz. Because of relatively high distances between the RIS, directional antennas are used here.

All components described in Figure 2 are interconnected via Ethernet (the available bandwidth ranges from 10 MBit/s to 1 GBit/s, depending on the device). For IT security, manageable VPN routers are applied that provide different and clearly separated virtual networks, each specific for the purpose and for the devices connected. The access control lists and rules implemented for this purpose in the router are very restrictive and only allow communication between the defined devices, on specific IP addresses and TCP/UDP ports. All communication between DLR and the stations (internet connection), and between the stations (WLAN mesh network) are encrypted and also secured by VPN.

A number of ITS stations (marked yellow in Figure 1 provide an uplink to the DLR's campus network via fiber or A/S-DSL internet connections, secured by VPN tunnels. Hereby, every single station can be remotely accessed and monitored by DLR staff. Furthermore, an automatic system for monitoring and remote control runs on DLR servers (see below).

2.2 Backend Systems and Software

As mentioned before, DLR runs a management system for remotely monitoring and accessing the devices in the field. All systems can be accessed directly (e.g. using their web interfaces or ssh). For an automatic and more efficient administration, the management system continuously monitors all the systems, supervises the accessibility of all machines and also the availability of services running on the systems. The state of each machine can be monitored and a map of all available RIS can be displayed. Furthermore, the system provides a software repository holding software binary releases and firmware. Software from the repository can easily be selected for automatic installation on specific devices or on all devices of the same kind. This allows an easy preparation of field operational tests and preparation of demonstration scenarios. Figure 3 shows the user interface of the management system, currently displaying status information of all the RIS.

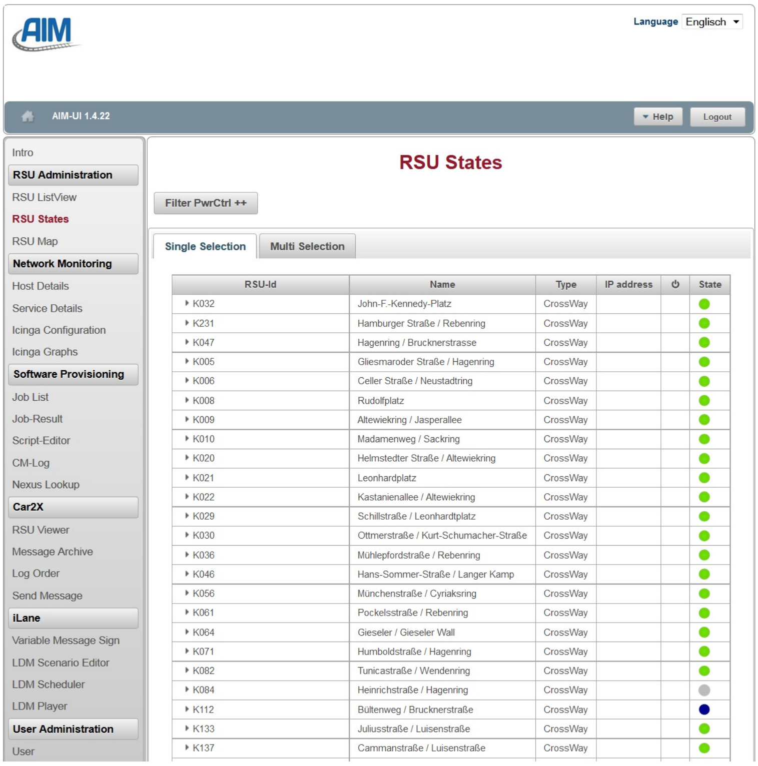

Figure 3: Screen shot of the management system.

Other services provided by the AIM Backend will be described in a dedicated article in this journal since they are also operated for other parts of the AIM platform.

3 Project Applications

AIM was designed as a platform for various research projects or direct cooperation between the DLR and partners. There are several examples of a successful application of the AIM platform and its services to recent projects.

3.1 National research project „UR:BAN“

UR:BAN (Urban Space: User oriented assistance systems and network management) is a large German national research project funded by the Federal Ministry for Economic Affairs and Energy. One of the sub projects addresses research and development of cooperative systems supporting the driver and improving traffic safety and efficiency. In 2015, several use cases were developed and tested by DLR and other project partners from the automotive industry. For example, the following use cases and applications were demonstrated:

- Intersection Assistant / Green Light Optimal Speed Advisory (GLOSA): Based on traffic light information provided by the infrastructure, the vehicle can calculate the optimal speed for approaching and passing the intersection, ideally without stopping. The RIS sends SPaT and Map messages. See Figure 4.
- Intelligent Traffic Pole: At a construction site, an intelligent traffic pole can be placed on the road. The pole calculates its position and communicates to the infrastructure. The RIS then sends DEN messages indicating the construction sites in order to warn the driver or to improve traffic efficiency.
- Emergency Vehicle Assistant: The traffic light system detects an approaching Emergency Vehicle (EV) and grants a green phase for the lane that this vehicle uses. All the other lanes are stopped

by red lights. The EV sends CAM messages indicating the vehicle's type, speed and alert state (light bar and siren in use). By decoding the message, the RIS determines the direction and reacts on the EV by switching to the correct phase, stopping any crossing traffic.

Figure 4: Example of the Traffic Light Assistant demonstrated in DLR's research vehicle.

3.2 Industrial Partnership projects

The test site can also be booked by private / industrial partners in order to perform customer-specific tests, e.g. for validating product requirements. One example is a cooperation with IAV GmbH from 2015, where cooperative applications had to be tested and validated. The project addressed driver assistance functions that used the traffic light and map information from the test site. In order to validate the system's behaviour, specific messages had to be sent by the infrastructure and the applications's reaction on these messages was recorded and evaluated. For example, false information (e.g. by packet errors) were sent to the vehicle, where the application had to deal with the erroneous information(Schonlau et al., 2015) (Schonlau et al, 2015). This example demonstrates the effectiveness of the test site, which is not only interesting for research activities but can also be highly valuable for the validation of near-market applications or systems.

4 Conclusion

The reference track as a part of the AIM research platform is a test track that supports development, evaluation, test and validation of cooperative ITS applications and driver assistance systems. DLR offers project partners or direct customers to use any part of the infrastructure, or to run projects in close cooperation. The facility if feasible for both research projects and direct cooperation, ensuring the required support or adaptation for the project's requirements.

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