MANAGEMENT OF ROADISDE UNITS FOR THE sim^{TD} FIELD TEST (GERMANY)

Manuel Fünfrocken *, Bechir Allani, Thomas Baum,
Arno Hinsberger, Jonas Vogt, Sebastian Weber, Prof. Dr. Horst Wieker
University of Applied Sciences Saarland, Goebenstr. 40, 66115 Saarbruecken, Germany

Abstract: The German project sim^{TD}[1] is the first large field test for cooperative vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in Europe. It consists of over 400 cars and over 100 roadside units (RSU). To manage that number of RSU new concepts are needed to ensure high system availability. The system management has to provide the following features: basic configuration, installation and maintenance of applications as well as fault management. Secure and reliable data transfer and a framework for applications is the base for the tasks mentioned before. Additionally an administration and monitoring interface for operators needs to be considered.

Introduction

Until now European research projects brought very valuable results related to integration tests and principal prove of concepts[2]. The focus of those projects was to prove basic feasibility but not to verify that V2X[3] communication can significantly improve traffic safety and efficiency. With sim^{TD} traffic impact becomes the main focus. German car manufacturers, suppliers, network providers, public institutions and leading research institutes form the consortium to realize the defined project objectives. The major goal is to prove the benefit of applications based on V2X communication, reflecting all requirements to a real-world system. Extensive experiments and tests will cover freeways and rural roads in the federal state of Hessen. City scenarios will be tested in Frankfurt am Main. The experimental area is shown in figure 1. The whole area is divided in four sections. Each of those sections represents a specific environment with individual qualities. Those are freeways with low RSU density, freeways with high RSU density, rural roads and urban roads.
RSU connect vehicles to existing and future roadside infrastructure including attached traffic control centres. Therefore they play a decisive role for the success of V2X systems in general and particularly during the introduction period.

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[1] This work was funded within the project simTD by the German Federal Ministries of Economics and Technology as well as Education and Research, and supported by the German Federal Ministry of Transport, Building, and Urban Affairs. [1]
[2] e.g. the following projects: [2], [10], [11], [12], [13], [14], [15]
[3] V2X covers V2V and V2I

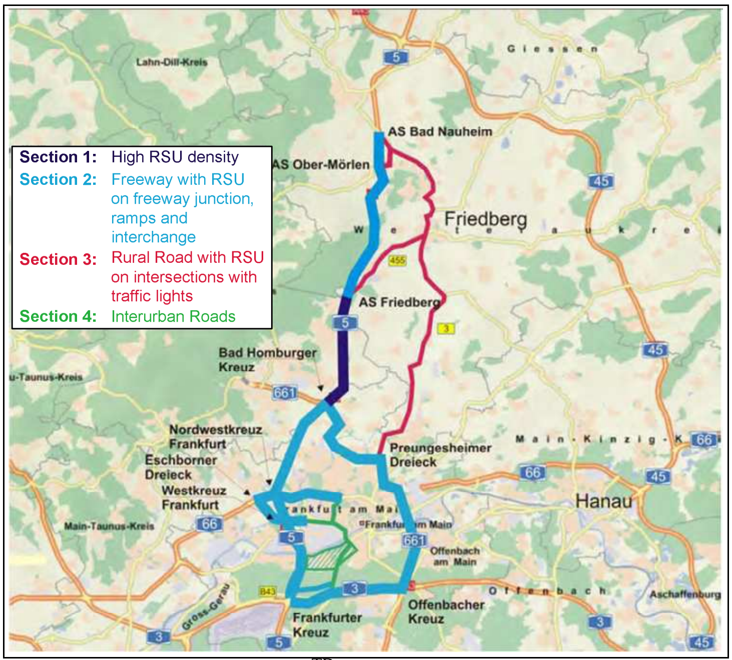

Figure 1: sim^{TD} experimental area [1]

RSU Management System

In a V2I environment, the RSU is responsible for the communication between vehicles, roadside infrastructure and the connected traffic management infrastructure. Additionally it is also responsible for extending the communication range of vehicles and to keep relevant messages available in their coverage area - independently from the network density, e.g. trough store-and-forward. Due to the high number of cars and the resulting network and resource utilization, decentralized fusion and pre-processing on RSU is highly recommended. To ensure scalability a distributed, hierarchic architecture for infrastructure bound functions[4] is desirable. Therefore the RSU provides a platform for any kind of V2I functions. It also, abstracts communication interfaces and system resources.

In order to ensure the availability of the RSU and its functions, a management system is indispensable. As physical access to the RSU from human operators is seldom possible in a timely manner, the management system must be full remote capable. To reduce the complexity and to enhance stability, it is divided into different interacting modules and sub-systems, which fulfill well defined and differentiated tasks:

- The *Configuration Management Subsystem* is responsible for maintaining the set-up of applications and the system itself.
- The *Fault Management Subsystem* is in charge of qualified handling of exceptional circumstances and failure.
- The *Function Framework* provides defined and controllable interfaces (e.g. V2I communication or system resources) for functions.

[4] According to the terminology of sim^{TD} all traffic related applications are called “functions”.

RSU Management Centre architecture

To achieve the above mentioned goals it is necessary to maintain a RSU Management Centre, which fulfils the requirements of high availability and scalability.

Figure 2 shows the hardware architecture, which reflects these requirements. A redundant and load balanced solution in combination with virtualization increases the robustness of the management centre and reduces the time to recover after a hardware failure.

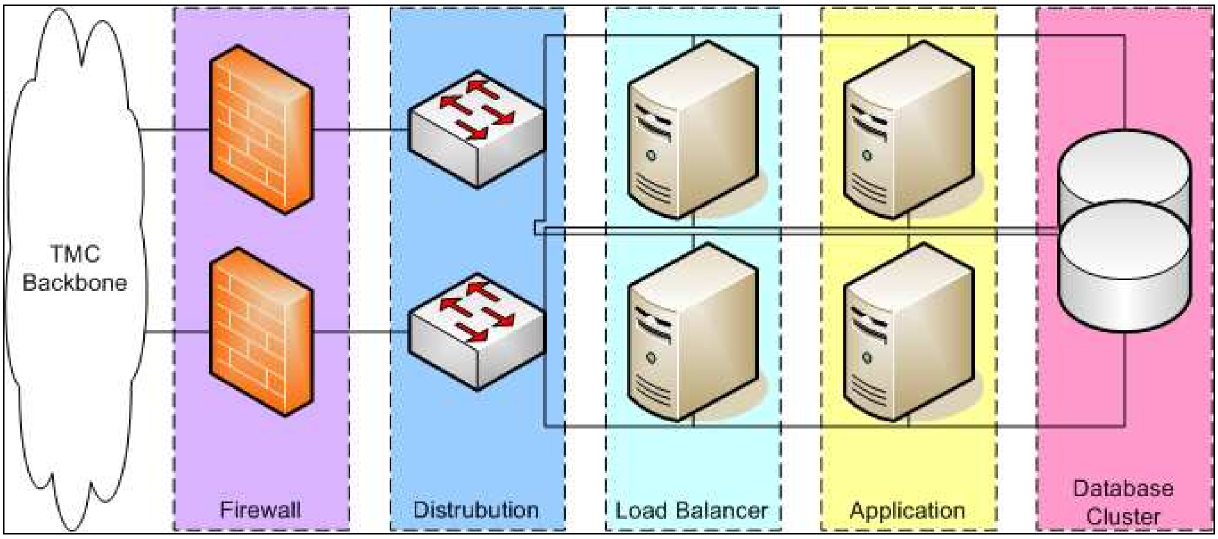

Figure 2: RSU Management Centre Architecture

All traffic directed to the management centre is scanned by the firewalls and afterward forwarded by the switching hardware. Then the traffic will be statistically distributed by the load balancers to the management servers. Those servers all contain the identical set of applications. So the computing power can easily be increased by adding new servers to the management centre. In combination with a database cluster this solves the challenge of scalability. The database cluster contains all information for configuration and management. This ensures that a failure of server hardware will not cause a critical loss of data and enables scalable extensions, as the RSU network is increasing.

RSU application platform architecture

The application platform on the RSU is divided into four logical parts: Configuration Management, Function Framework, Fault Management and communication modules. These communication modules are:

- V2I Communication which handles the communication to the vehicles.
- Test Centre Communication Module provides communication to centre based functions and management subsystems.
- Infrastructure Equipment Communication Module enables interaction with e.g. traffic light control systems.

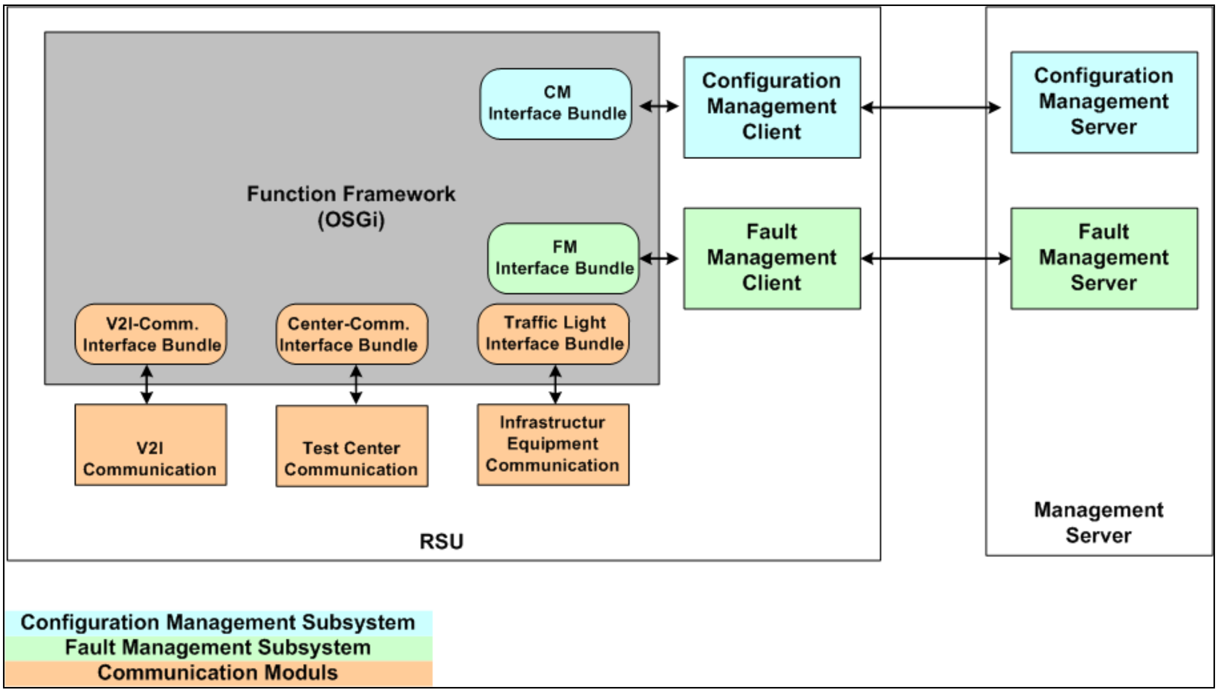

Figure 2: RSU Architecture

In the following section the subsystems Configuration Management, Fault Management, Function Framework and the communication modules will be described.

Management Subsystems

Configuration Management (CM)

In the sim^{TD} scenario it is possible that some applications are only used for special tests or just on a dedicated set of RSU. Therefore the Management System needs to provide the possibility to easily reconfigure single RSUs, which means to (re-)install, reconfigure and to (re-)launch functions as required according to the current test scenario.

In addition to that Configuration Management has to be capable of changing the configuration of the system itself as well as the functions. Because the RSU is meant to be a flexible platform for any kind of V2I functions, the CM subsystem needs to handle functions as well as systems applications in the same way. This allows an efficient and flexible implementation of the management system. To achieve this flexibility, the Configuration Management uses an advanced package management system and a configuration framework.

To achieve the afore-mentioned goals CM comprises of two co-existing parts (see Figure 3):

- Applications & Resources part: Handles applications and their resources like libraries, images etc.
- Configuration part: Handles all the properties and other configuration that has to be done on each RSU.

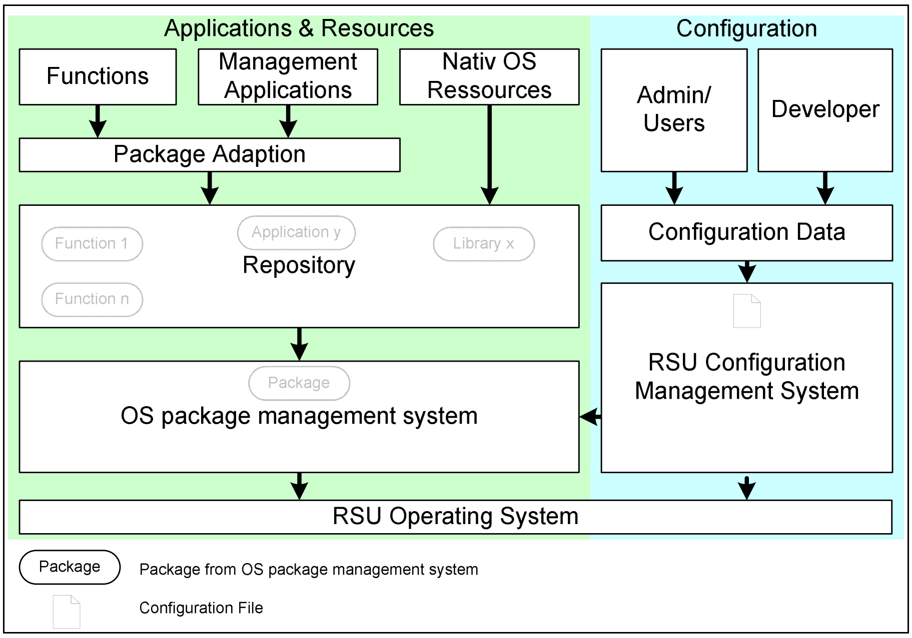

Figure 3: Structure of the Configuration Management

As one can see in Figure 3, different kinds of input for each part are aggregated into a common representation. That means data from different sources are standardized and aggregated in a well-defined container format. For the Applications & Resources part, this is a package compliant to the package management system of the underlying operating system. This aggregation enables the OS package management system to maintain native OS-packages as well as sim^{TD} specific functions and management resources. This approach does not only reduce the complexity of the overall management it also increases maintainability and extensibility.

The configuration data for each application and RSU is stored in a central database. This decouples the configuration process from the insertion process. This means that it is irrelevant for reconfiguration whether the data has been changed by a human administrator, another subsystem or other sources. Furthermore it allows a persistent storage of the configuration even if a RSU has to be replaced; e.g. Mobile RSU systems for roadwork scenarios. For the means for configuration and administration, a replaced RSU can be autonomously reinstalled and reconfigured.

Fault Management (FM)

Fault management is also equally distributed. Accordingly it consists of interacting RSU- and center-bound counterparts.

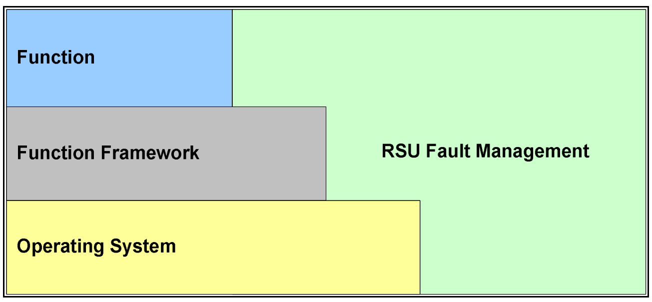

Figure 4: RSU Fault Management

On the RSU, Fault Management is present during the boot process of the operating system and observes the integration of the function framework and the functions. Figure 4 shows the three monitored parts for which the fault management is responsible.

Fault Management comprises the following tasks and processes:

- Classification and definition of failures
- Local system verification
- Network management
- Log events analysis
- System components tests
- Monitoring data collection
- Error fixing by applying predefined strategies

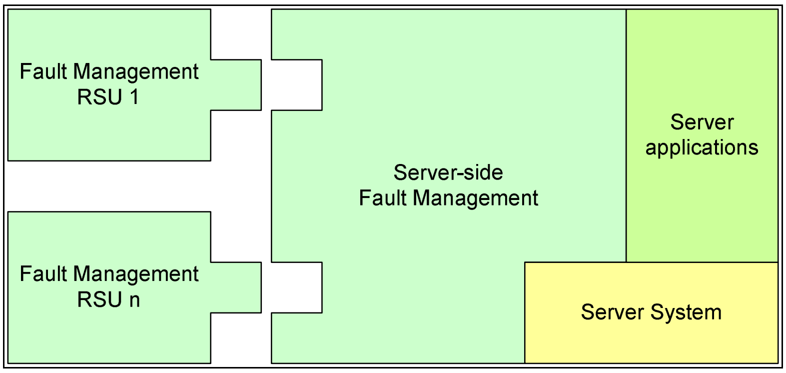

Figure 5: RMC Fault Management

The centre part of the Fault Management is built up as a counterpart to the corresponding RSU modules. Its responsibility is divided in two parts: On the one hand the supervision of the server-sided processes and on the other hand the accumulation of messages from the RSU Fault Management. The Centre Fault Management is therefore a service provider and a decision-maker to the RSU Fault Management.

All operations of the entire management system and its processes are supervised by the Fault Management. In addition, all system information is gathered centrally. So it is also available for extensive system analyses.

Function Framework

All functions, which run on a RSU platform use various interfaces and differently consume system resources. RSU Management guarantees that all coexisting functions can use these interfaces and resources (CPU-time, RAM- and disk space, bandwidth, etc.), without overloading them. For a reliable operation it is essential that the remote RSU systems are accessible for the central management subsystems at any time. This means that a sufficient amount of communication and system resources must not be utilized by functions. RSU functions themselves are of different importance. Accordingly the management has to ensure that high priority functions always prevail over low priority functions in terms of resource consumption. To ensure the afore-mentioned requirements functions are assigned to dedicated limits concerning the use of communication and system resources. The Function Framework is indispensable for the management subsystems in order to provide consistent and controllable application interfaces to all kind of resources. An extra, independent framework

maintains all management components. This ensures that the RSU system remains maintainable in case the application framework fails.
The Function Framework is realized as an OSGi [9] Framework. Each function and each interface is represented by a bundle. As the OSGi Framework is a service oriented architecture, each interface is defined as a service. The functions are consumer for the services provided by the interfaces and vice versa.

Communication

On an RSU the bandwidth of all communication links is limited. This concerns the radio interface to the vehicles but also the centre connection. Therefore the amount of traffic is limited for each RSU function. Related configuration for each function is stored in the central database of the RSU management system. The limitations may only be configured by the management instances and are enforced on the RSU. This assures that the communication bandwidth of a certain link is not consumed by just one application. Available bandwidth varies from RSU to RSU and depends from the communication media, the number of co-existing RSU applications and applied protocols. These connections can be private or public and shared or exclusive physical channel. The RSU must be able to operate with the associated underlying conditions like bandwidth or delay. In sim^{TD} three kinds of access technologies are used: fiber optical channels (FOC), Universal Mobile Telecommunications System (UMTS) resp. General Packet Radio Service (GPRS) [8] and Digital Subscriber Line (xDSL).

These communication media have very different bandwidths[5] and similar different delays. The needed limitations for communication are thereby adapted to the actual used communication technology. The most important intension is that the RSU remains maintainable, because no application can completely congest the connection between the RSU and the centralized management subsystems.

In general the RSU can be considered as the link in the communication chain between central- and vehicular applications. Thereby it has to combine very different communication processes, which necessarily need to be decoupled, at least for traffic safety and efficiency functions [3]. While the centre communication is widely based on common point-to-point, connection oriented, TCP/IP interaction, V2I communication has to adapt to the current availability of neighbors, the current network density and the very narrow bandwidth, which has to be shared with all other functions on all neighbored vehicles in a distributed manner [4]. In order to ensure compatibility the RSU system is necessarily based on the ITS Station Reference Architecture as proposed by [15] and [16]. This means that the basic communication mechanisms like e.g. network layer routing and transport as well as Application Support Facilities (CAM, DENM, etc.) are equal on RSU and vehicular units. But in order to bring messages from centre applications to the addressed group of vehicles the RSU needs to extend this architecture with intelligent algorithms for buffering and the distribution of messages. Sophisticated approaches for the distribution of centre information in the vehicular network adapt to the current traffic scenario, the local channel properties, the application's priority and message properties, while at the same time ensuring a defined level of redundancy.

In sim^{TD} two wireless technologies are used: IEEE 802.11p (pre-standard) [7] for safety- and traffic efficiency based vehicle-2-vehicle and vehicle-2-infrastructur communication and

[5] From approximately 10 MByte/s (FOC) to not more than a few Kbyte/s (GPRS)

IEEE 802.11b/g [6] Wireless LAN for vehicle-2-infrastructue communication for the distribution of some service-oriented information and for the sim^{TD} experiment logging.

All these communication technologies have one thing in common; they are used for the distribution of sensitive information that at least has to be authenticated or better encrypted. So for different types of communication adequate approaches for security have to be taken. The security for IEEE 802.11p communication is based on the IEEE pre-standard 1609.2 [5]. This is planed also to be used for the IEEE 802.11b/g ad-hoc communication whereas the IEEE 802.11b/g infrastructure communication should be protected with IEEE 802.11i [6].

Conclusion

The distributed RSU Management System provides system wide maintenance of all RSU in the test field. The RSU in sim^{TD} combines the two very different worlds of Vehicular Ad-Hoc communication with the connection oriented traffic management systems including all their various protocols. Thereby the RSU Management System offers an efficient and reliable environment for all test field functions. The system guaranties a 24/7 availability and a fluent processing of all tasks in reference to the functions. It is a self-organized system, which means that it is able to recover autonomously from exceptional circumstances to the normal operation. The presented system architecture reflects all aspects, which are of importance for an RSU network in the real world, starting from communication aspects throughout management and maintenance as well as a reasonably distributed organization of infrastructure applications. Therefore the proposed solution is not only relevant for the execution of field trials; it is explicitly developed for the real world operation of an RSU network.

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