Architecture of an Always Best Connected Vehicular Communication Gateway

Erik Weiss, Maciej Muehleisen,
Carl-Herbert Rokitansky, Bernhard Walke
Communication Networks, Faculty 6
RWTH Aachen University
Aachen, Germany
erik.weiss@comnets.rwth-aachen.de

Laura Georgi
Service Management Department
Research Institute for Operations Management
at RWTH Aachen University
Aachen, Germany
Laura.Georgi@fir.rwth-aachen.de

Abstract— MobilitY and CollAboRative Work in European Vehicle Emergency NeTworks (MYCAREVENT) is an European Project of the 6th Framework Program [1], and aims to optimize the European market for automotive after sales services and repair. MYCAREVENT develops innovative applications and services, which can always be accessed seamlessly and securely using mobile communication. Maintenance situations like car breakdowns or minor failures happen everywhere. Wherever such an unpleasant situation appears, the driver needs help and advice - most likely provided by a roadside patrol. To support roadside technicians and drivers with MYCAREVENT products and services, a mobile communication following an "always best connected" approach facilitates the communication between the mobile users within a collaborative work environment. This paper presents the vehicle communication gateway (VCG) and its protocol architecture developed in MYCAREVENT.

Keywords-- MYCAREVENT; Always Best Connected; Car Gateway; Media Independent Handover;

I. INTRODUCTION

MYCAREVENT is strongly supported by car manufacturers, independent and dependent road assistances services, telecommunication providers, software developers, diagnostic tool manufacturers, and leading academics for a sufficient coverage of the competences needed to perform the challenging task of providing mobility successfully [1]. Within MYCAREVENT, 20 partners develop and implement new applications and services, which can be accessed seamlessly and securely. These services will provide the customers with manufacturer specific repair information according to the problems identified by diagnosis systems. Mobile communication will be used to communicate with the On-Board Diagnostic (OBD), to gather breakdown information (see [1]) and to access web based services for repair information. This information will primarily support the technicians. Still, additional services providing drivers with specific information are another aim of MYCAREVENT. Using pan-European technical standards, the results will be transferable to other industries, which call for mobile services. Mobile communication enables the exchange of fault messages (via error codes) and repair information and thus allows for complex repairs at the roadside. Figure 1 shows the information flow to conduct this service from failure to the restored mobility. Starting with the car reporting a failure, subsequent information is transmitted

This work was supported by the European project MYCAREVENT (IST-004402), www.mycarevent.com.

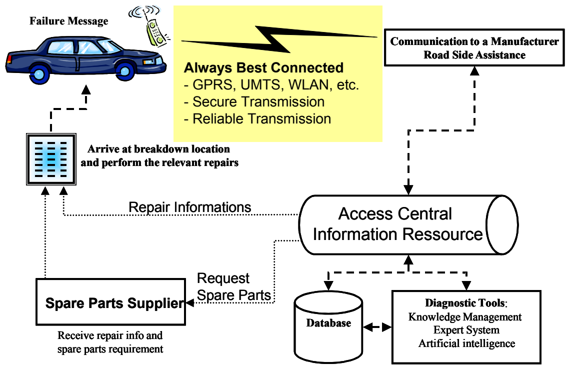

Figure 1. Example Information Flow

to a service provider using mobile communication. This error message is analyzed with an existing database, guidance and repair instructions are provided, and if necessary, a process to deliver additional spare parts is initiated. Transmitting the information enables the roadside assistance solving the problem. The MYCAREVENT consortium investigates the potential of various mobile devices and communication networks and designs an "always best connected" network for the roadside patrol and the driver. Facing repair and maintenance situations, fast movement or rural countryside environments are substantial challenges for the performance of mobile communication networks. Furthermore, different mobile communication systems can be applied, like GSM, implying GPRS or UMTS, as well as short range communication like WLAN or DSRC. If none of those classical communication systems is available, vehicle-to-vehicle communication and/or satellite communications will be used. The envisaged communication solution aims at facilitating today's communication systems as well as mobile communication concepts such as Beyond 3G and hybrid systems. A prototype demonstrating this "always best connected" network solving these technological challenges will be developed within MYCAREVENT.

II. USE CASE

MYCAREVENT addresses different technical areas, such as manufacturer dependent and independent workshops and roadside assistance and aims at providing these with case specific services. Particularly for the use case involving roadside assistance, mobile communication is one mandatory enabler, which demands primarily for mobility. The same goes for the technician who as well should be able to work mobile in the workshop. Thus, his laptop will be attached to WLAN or Ethernet in the garage, and to WLAN or GPRS/UMTS in order to access the repair instructions on site. The technician experiences only the performance change of the new communication medium. While attached to WLAN, the technician can be supported with multimedia information guiding through the repair, by using e.g. video streams showing the detailed assembly process of spare parts or interactive circuit diagrams. While on the move and attached to GPRS/UMTS, the service will be tailored to available transmission resources, waiving of video or large animation transmissions and focusing on plain information.

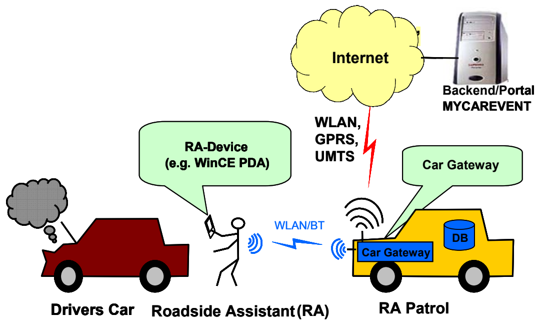

Figure 2. Roadside Assistance requests additional repair information

Special attention must be paid to the roadside assistance (RA) or in general technician not implicitly being able to configure the communication device in case of technological changes. Furthermore, the laptop of the technician is used and maintained for repair guidance only and complex communication software should be avoided. MYCAREVENT searches for a solution that could be universally applied for different devices, operating systems and software. Based on the mentioned requirements, the concept depicted in Figure 2 was developed. To accomplish repair services, the RA uses his 'normal' laptop and software, which assembly are commercial products of the shelf. As communication center, a mobile vehicular communication gateway (VCG) is integrated to the RA's car. The VCG manages all communication related issues, e.g. deciding about the best communication system. The VCG is configured and maintained from the backend. The backend is able to change settings and modify/add the contracts with new operators. Hence, the RA is the user of the VCG and not the maintainer being involved in the configuration of the gateway.

It is important that the gateway as well as the network side is up to date about the actual transmission conditions. Based on this, the operation and maintenance centre (OMC) at the service portal will be able to configure, and to some extend control the behavior of the car gateway.

Beside the depicted use case, the gateway might also be placed in a common car. In this case the gateway is not only responsible for communicating error codes or repair guidance, but also manages car internal communication (infotainment).

III. Business Modelling for VCG

The vehicle communication gateway supports the application of MYCAREVENT services and products and offers significant advantages compared to conventional communication technologies. A new business opportunity for network operators or "virtual" network operators with different radio access networks arises, as they can offer this gateway to customers in order to fulfill the "Always Best and Secure Connected" requirement. Yet, the use of VCG requires an investment, which needs to be compensated by an appropriate value for the investor. The VCG itself may not offer an adequate argumentation to justify the expenses; but set in relation to the extensive options offered by MYCAREVENT services and products, a large benefit for the use of VCG can be presented.

Therefore, business models unifying VCG and all elements of MYCAREVENT services and products need to be designed. A typical example for such models is the mobile phone market, where the phones themselves are sold at a much lower price, which is compensated by a monthly fee. However, as this model bears large disadvantages for the mobile operator, currently new approaches (like an interest-free credit) are under evaluation. According to the different aspects and requirements arising from the different users in the MYCAREVENT area, different business models and pricing strategies which suit the users' needs will be defined within the project. In order to implement innovative business models for complex services, a consistent and systematic approach is required. The chosen methodology provides a feasible and sustainable framework for business modeling in a collaborative networked organization context. The relevant market participants have to be determined and their business activities have to be analyzed on sub-model level [7]. Business relations can be examined and documented using business maps, which give important hints on how changes to the business models have an impact on each participant's environment [8]. Eventually, the interoperability between the market players has to be ensured. In the context of VCG, two major participants can be identified: the road side assistant being part of a business organization and requiring mobile support in everyday's life, and the driver as a private person with occasional break-down situations. The benefit of a VCG in combination with an easy and mobile access to repair instructions is evident for road side patrols. This fact cannot be simply adapted to the drivers' demands. Thus, the benefit needs to be established by extending the options, i.e. elements increasing the value significantly, e.g. by adding services needed in the drivers' everyday's life, such as navigation support, communication etc. These services need to be enabled by appropriate contracts.

For the contracting, pre-negotiated, periodic, bi-lateral and pre-paid contracts on one side, and ad-hoc, one-time, multilateral and credit based solutions on the other side are options to be applied for mobile services in combination with hardware like VCG. To simplify the complexity of challenging business modeling for this article it can be stated that e.g. pre-negotiated contracts appear more convenient for road side assistance organizations. As the mobile support can be performed more efficient if the driver's car has a VCG, another option for the RA organization could be to integrate the VCG hardware in the service offerings for their customers – the drivers. For the drivers themselves, MYCAREVENT service packages need to be defined to conduct an attractive benefit case for making such an investment. In the course of the project, the MYCAREVENT consortium develops individual business models with respect to the different interests of the different involved parties: car manufacturers, service providers, potential customers.

IV. Communication Requirements

The previous section has described in brief some of the use cases addressed by MYCAREVENT. The major requirements supporting the roadside technician are listed below:

1. The gateway chooses the most suitable communication system. This decision will be based on user policies and service parameters.
2. The communication has to be secure, if required.
3. The quality of service (QoS) of the connection should be monitored, adapted and switched if the connection performance falls below the required quality of service parameters.
4. Switching the wireless network should be transparent and seamless for the application.
5. To ensure reliable transmission of critical information or software, the connection should not exceed a certain configurable packet error rate.

V. Always Best Connected for Next Generation Vehicular Communication

Vehicular communication has been a research topic for many years. It comprises car-to-car (C2C) and car-to-infrastructure (C2X) communication. MYCAREVENT focuses on C2X and develops a vehicular communication gateway, which is able to incorporate today's communication systems and approaching techniques of the next generation as well. The requirements for the car-to-infrastructure communication of the gateway contain some important differences compared to the published work of session mobility protocols (cf. Figure 3).

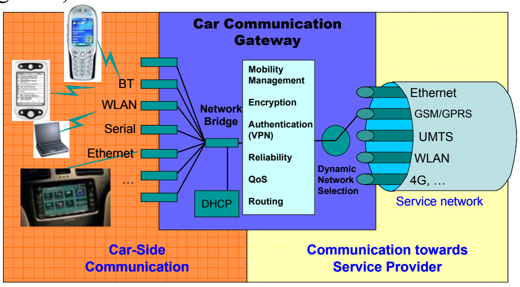

Figure 3. Gateway Functionality

1. The car gateway always connects to only one Service Portal, and the requested information is hosted there or at least in the referred service network.
2. Both, the service network and the driver control the behavior of the car gateway. The car gateway usually does not act autonomously but is assisted by the network.
3. The reasons for a system's change might vary from only loss of coverage or availability.
    a. Security requirements
    b. Reliability requirements
    c. QoS constraints
    d. Service requirements

Furthermore, the car gateway does not only manage the mobility for its own traffic; the gateway manages the mobility of all attached devices within the car. This could be the roadside patrol's laptop, the drivers PDA or the in-car telematics unit, as well. The centre part of Figure 3 gives an overview of the functionality of the communication gateway. The gateway incorporates several communication systems to connect the car with the service provider, e.g. UMTS/ GPRS and WLAN.

On the right hand side of Figure 3 the communication towards the service provider is depicted. Several communication media are envisaged. A dynamic network selection chooses the most suitable communication medium. Moreover, this could also be a combination of two or more parallel communication technologies. The functions mobility management (MM), encryption, authentication, QoS mapping, enhanced reliability and routing are shown in the middle of Figure 3.

The left part describes a classical gateway design, except that many different technologies can be used to attach to the gateway as the central point of communication. Mobile devices, such as the roadside patrol's laptop, driver's PDA or in-car telematics units will be able to connect to the gateway. Thus, the gateway offers an advanced communication service.

VI. Vehicle Communication Gateway (VCG) Protocol Architecture

The protocol architecture of the VCG is related to the 802.21 Media Independent Handover (MIH) reference model [2]. Information services to various arbitrary link layer protocols, like GPRS, UMTS, 802.11 (WLAN), DVB-T, 802.16 (WIMAX) are foreseen. The current prototype consists of GPRS, UMTS, and WLAN. The Mobility Management and Network Selector base on a messaging process that is oriented on the MIH information services [2] and provides the application layer and the OMC with an interface to control the behavior of the network selection.

The gateway establishes an encrypted UDP tunnel to the security gateway. The UDP tunnel switches between different

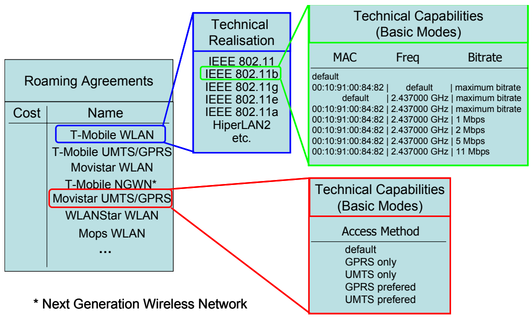

Figure 4. Creation of Communication Modes (Basic Modes)

communication systems, depending on the required QoS and the allowed costs for communication. This layer is tightly coupled with the IP protocol. The address of the IP layer is the never changing virtual IP address of the communication tunnel endpoint which is connected to the security gateway at the service provider. Thus, the application on top only uses the virtual address of the tunnel endpoint. The algorithms to determine the communication system and to handle the mobility are described in the next sections.

A. Media Independent Handover (MIH) Layer

The Mobility Management & Network Selector of the Vehicle Communication Gateway uses events from the MIH layer. The MIH layer couples within the Control Plane to layer 2 functions of each specific communication system and within the user plane to the IP layer of each system. The Network Selector function bridges the QoS requirements coming from the application with the current condition of all available networks. The application and configuration interface provide policies covering the required QoS, security, and reliability demands regarding the communication and contractual limitations. This policy will be applied to the available communication modes to form the respective rule tables. The Network Selector evaluates these rule tables according to the triggers coming from the MIH layer.

B. Mobility Management & Network Selector

The decision about the used network is based on communication modes. Each mode contains technical details, like MAC address, frequency, bitrate and contractual agreements, e.g. cost model, or roaming agreements. The important differences regarding a certain communication technology are stored as one mode to operate. In addition, the operation and maintenance centre (OMC) at the service portal, which configures the VCG might update the list of possible communication modes. This list serves as basis and contains all allowed communication modes. Each communication technology has certain indicators describing the performance of a network, e.g. typical information for WLAN is the used bitrate (PHYMode). Other parameters are the used frequency or the exact MAC address of an AP.

C. Generation of the Mode Database

The basis for the network selector is the generation, maintenance and monitoring of the basic communication modes and rules. Each VCG has a predefined list of possible/acceptable modes, this list is kept up to date by the OMC. The VCG compares the acceptable nodes with the existing ones at the current position. The construction of communication modes is depicted in Figure 4. All acceptable modes together form a complete list of basic modes. Figure 4 shows exemplarily the reduction of the mode list for the WLAN and UMTS/GPRS interface.

WLAN modes contain provider name, communication cost, WLAN technique, frequency, bitrate and MAC address. The MAC address and the frequency are stored to allow a fast change and a focused scan method. However, the most important parameter is the experienced bitrate, which depends on the applied PHYMode. A certain service might require a data rate that cannot be served with low bitrates. The list of possible

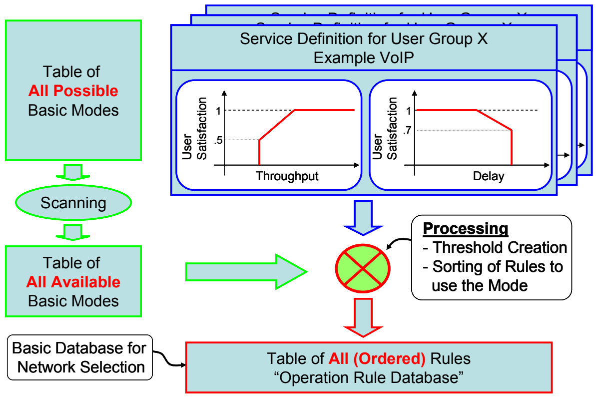

Figure 5. Generation of Operation Rule Base

modes is distributed by the OMC and only depends on the available communication interfaces of the VCG.

The VCG scans all interfaces and searches for available communication systems and mobile operators. Based on the found communication modes, the VCG controls the list of possible communication modes and compares which modes are allowed from the OMC and which modes are currently available. This step reduces the list of possible communication modes to the available modes, which serves as basis for the decision at the current position. The VCG scans permanently with all unused interfaces to monitor the list of available modes, adds the modes of new detected providers and eliminates modes that are not longer available. The VCG correlates the list of available modes with the policies describing the required QoS. The correlation result is the excellence of a mode with regard to the requested QoS. The excellence described the accordance of a mode with the required QoS. The combination of mode and excellence is called a rule. The table of achievable modes (Basic modes) is correlated with service specific QoS parameters (throughout, delay, etc.) and the excellence of each mode is calculated, see Figure 5.

Figure 6 depicts the relation between rule and mode. The application specifies a policy describing the required service. A policy describes each QoS parameter using distribution functions (see Figure 5). The correlation between mode performance and policy results in a value that specifies the excellence of each mode. This value is used to sort the rules with regards to suitability. The rule the top of the list is the best mode for the required service. In Figure 5 the QoS parameters for VoIP are depicted. VoIP requires a minimum amount of throughput and tolerates only a maximum packet delay (limited voice coding). The usability of VoIP starts with those values but the user satisfaction increases with higher throughput and lower packet delay. Increasing the throughput and delay makes only sense until the VoIP-Service is fully operating and the user is satisfied; at this point a further increase is not necessary but in general does not violate an optimal service either. The communication rules which fulfill the service requirements with a specific excellence are listed in an ordered table, called Operation Rule Table. Each rule is controlled if the actual communication system offers this rule. The highest available rule in the operation rule table contains the best communication mode for the required service. The utilization of one mode is specified by a rule for each mode. The rule, shown in Figure 6 contains firstly the exact definition for the mode, and secondly its grade of excellence for the required service. The third block contains thresholds and state information.

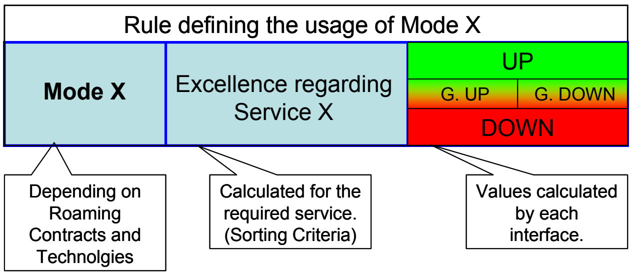

Figure 6. Relation between Mode and Rule

These thresholds allow the network selector to evaluate how to use that particular mode. The scanning process determines the available modes. In addition, each mode is associated with measurements, such as received signal strength (RSS), packet delay or packet error rate. Those values are controlled if the measured parameters are sufficient, the mode is rated as 'UP' and usable. With measured parameters being insufficient, the mode is rated as 'DOWN' and cannot be used. Beside those two states a rule can be in two intermediate states 'GOING UP' and 'GOING DOWN'. Both states are used to allow a smooth changeover between modes. In case of a rule having a higher excellence than the currently used rule and the state changing to 'GOING UP', the VCG initiates a connection via this mode. The tunnels is switched to the new mode as soon as the new mode finally changes to the state 'UP'. The behavior is similar if the current mode changes its state to 'GOING DOWN'. The next higher rated mode is used to initiate a connection, and the tunnel is switched to the new mode as soon as the initialization finishes. This algorithm ensures that the tunnel is always routed via the best communication system.

D. *Assisted Location Based Mode Decision*

The performance of the VCG can further be improved by introducing position knowledge. The mode list created by the VCG is valid for an actual position and is stored in a database linked to the position. Similar concepts have been presented in [6].

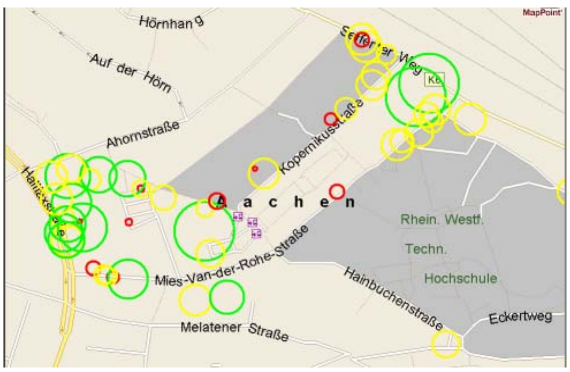

Figure 7. Data base of WLAN Mode Positions and Ranges

Figure 7 shows a map section containing the position and range of WLAN modes, the green circle represent stable modes, yellow and red identify categories of less stable modes. This supports the RA such that when approaching this position a second time, the database informs the network selector upfront about the approaching modes. The network selector uses the stored information to cut short the scanning process and thus the creation of the available basic rule table. This shortens significantly handover times and hence, increases the dwell time of the VCG within cells.

VII. CONCLUSION AND OUTLOOK

This paper presents the MYCAREVENT project and the developed car communication gateway. The addressed use cases are outlined and the requirements for mobile communication and the mobile vehicular communication gateway are described. Based on the use cases and requirements an advanced car communication gateway has been developed and the different functions are explained. The VCG will be configured remotely and allows e.g. roadside patrols to concentrate on their repair job while always using the best communication. The MYCAREVENT consortium develops a live demonstrator to show the benefits and efficiency of mobile communication for automotive after sales services.

VIII. ACKNOWLEDGEMENT

The authors would like to thank the members of the project for the valuable discussion.

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