Integration of an Advanced Emergency Call Subsystem into a Car-Gateway Platform

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***Abstract*— Several European research projects in the vehicular area address the enhancement of vehicular safety. In the frame of the Caring Cars project, an on-board car-gateway embedded architecture for safety and wellness applications has been designed. This paper puts forward the essentials of this modular, dynamic and robust architecture and defines in detail the advanced emergency call (eCall+), one of the most innovative applications in the project. By mean of the eCall+, the emergency services will always be able to track the affected vehicle and monitor the state of the car. The driver may also contact them through videoconference in a critical situation. Thus, the system can either prevent an accident or help the vehicle occupants and the emergency services to safe the occupants' lives after an accident occurred.**

Keywords-component; eCall, eCall+, emergency, safety, automotive, localization, services

I. INTRODUCTION

The emergency call initiative aims to obtain a very fast reaction from the emergency services after an accident has occurred. This may reduce the probability of death in road trips. By using the current emergency call system from the eSafety initiative[1], the emergency services operating from the Public-safety Answering Point (PSAP) can instantly identify the vehicle's location and establish a phone call to evaluate the seriousness of the accident.

This paper describes a more advanced emergency call (eCall+) approach that provides the emergency services with enriched information about the state of the car as well as establishing a videoconference between the car occupants and the PSAP assistants.

The eCall+ is not just an optimized eCall system; it is a very powerful tool that has been developed in the context of the Caring Cars project addressed to improve the safety and wellness of the car occupants via computational systems. Due to that, the eCall+ is supported by a complete hardware and software architecture that takes advantage of further telecommunication systems, services protocols and sensor networks. As a result, this project will obtain a modular, robust, dynamic and expandable emergency system composed of a dual on-board computational unit characterized by a very high reliability under accident conditions. The goal of this paper is to describe this modern concept of an on-board embedded emergency system and the eCall+ application as well as defining the hardware and software architecture, and the communication technologies supporting the system.

This paper is organized as follows: Section 2 presents the related work. Sections 3 to 6 define the system in detail. Section 7 presents the prototype and Section 8 summarizes the work.

II. RELATED WORK

The eSafety Commission efforts in the eCall initiative pursue the integration of the emergency call and the emergency services. Their proposal is stable and widely used but the functionality is limited as some of their technical reports about the in-vehicle unit [1] and the PSAP [2] show.

There are multiple studies around the implantation of safety telematic systems in vehicles. In [3], the GTP protocol for the communication between a vehicle and the PSAP is proposed. They use SMS as transmission protocol, so they cannot transmit much information about the vehicle state. Another work [4] proposes the NOW (Notification by Wireless Systems) architecture for automatically detecting an accident and warning the emergency services. The automatic detection is based on a sensor network. In spite of the data retrieved from the sensors and delivered to the emergency services, this system does not allow the communication between them and the vehicle occupants. This work does not solve the communication between the on-board devices and the NOW server either.

By means of the eCall+ described in this paper, the emergency services can watch the state of the vehicle in real time thanks to the video, audio and data connections. They are also continuously receiving the data retrieved from the sensor network. By using UMTS (Universal Mobile Telecommunications System) for communication and

[1] http://www.esafetysupport.org/en/esafety_activities/

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advanced service protocols for exchanging information, the technology does not limit the possibility of extending the eCall+ in the future.

Some approaches propose SIP based systems, like [5] and [6], but they do not solve problems derived from a mobile environment as the vehicular one. With the eCall+, the objective is to move this kind of advanced functionalities from a fixed context to a mobile one.

Another interesting proposal is described in [7]. This is a system that automatically detects and advices the driver from unforeseen events on the road. Although the Caring Cars project does not consider this functionality, the platform described in this paper offers an infrastructure to easily deploy similar services.

Currently, the number of studies on the vehicular safety improvement is increasing. This assertion is supported by a large list of current projects researching in this line, e.g. SAVE (System for Effective Assessment of the driver state and Vehicle Control in Emergency situations), EASIS (Electronic Architecture and System Engineering for Integrated Safety Systems), etc.[2]

III. GLOBAL ARCHITECTURE

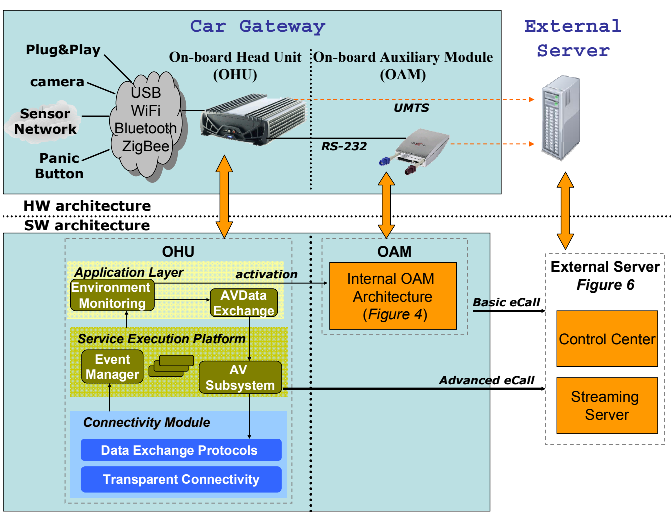

Figure 1. eCall+ architecture. Top-down the hardware elements and the software modules.

The distributed architecture in the Figure 1 has been defined in order to support the eCall+ application. It is made up of two elements: The dual mobile unit (the car-gateway) installed in the vehicle and the fixed external server on the PSAP side. In turn, the car-gateway is divided into two elements: The On-board Head Unit (OHU) is the main element of the vehicular unit. It triggers off the eCall+. The On-board Auxiliary Module (OAM) is a higher-robustness unit that triggers off the basic emergency call in case the OHU was seriously damaged or the link between the two units is lost. Thus, this redundant system ensures that at least the basic eCall will always work correctly.

Following, the OHU, the OAM and the communication infrastructure will be described in more detail in the following sections.

IV. ON-BOARD HEAD UNIT (OHU)

The OHU is the on-board element that establishes the eCall+. The eCall+ is defined as a bidirectional connection between the vehicle and the PSAP where some multi-format data including AV, videoconference, voice, sensed data and localization information is delivered at once in order to improve the emergency services assistance.

The OHU is attached to the in-car sensor network as a master node. It is also equipped with a panic button. Data from these inputs enables to detect emergence situations. It is also equipped with a camera for the videoconference. The communications with the external server are supported by a UMTS interface. The OHU architecture is designed to support any other local plug & play device that can supply data about the state of a vehicle and its occupants, for instance, some wearable wireless sensors. Those elements are attached to a LAN where the OHU is the gateway that interconnects the devices one to each other and with the external server by means of a Vehicular Ad-hoc Network (VANET).

The OHU software is a multilayer architecture that supports routing, data exchange, multimedia communications and device discovery tasks at different levels.

- The **transparent connectivity** layer supplies UMTS and VANET compatibility. The eCall+ runs over Internet protocols so both of them provide appropriate channels for TCP/IP in a mobile context. This layer also manages other communication technologies as Bluetooth, WiFi and Zigbee for a full connection between the OHU and the local devices and the sensor network. The transparent connectivity provides a standard API to access to any heterogeneous network from the upper layers.

- The **data exchange protocols** layer implements the application level protocols for service invocation (network services). It is based on the UPnP standard [8] but adapted to the remote service access (UPnP is conceived to local networks). Thus, the PSAP can be accessed from the car-gateway as a local device. To do this, the car-gateway a priori knows the IP address of the PSAP, so the broadcast device discovery phase of the UPnP protocol is avoided. Security at this level is supplied by UPnP services that encrypt any service invocation before sending any request through the network.

- The **service execution platform** layer offers some OSGi[3] [9] services: the event manager and the AV subsystem. The event manager service unifies

[2] This information belongs to the eSafety European Commission web: http:// www.Esafetysupport .org/en/ safety_activities/related_projects/

[3] OSGi is a middleware development framework.

different eventing models (OSGi, UPnP and Java) in a standard mechanism for the notification of asynchronous events. This service allows the monitoring applications registering different events to be dispatched to the emergency applications observing a priority schema. The AV subsystem service implements the AV UPnP [10] specification for the AV exchange. This service manages the video streaming in the videoconference and the AV contents exchange applications.

- The **application** layer joins the detection engine (implemented by the environment monitoring service) with the eCall+ execution (located in the AV data exchange service). The environment monitoring consists of an event listener that subscribes dynamically to every event registered as emergency signal. This is belonging to the `EMER SIG` event class. Either the panic button or a crash sensor can dispatch this type of events. The data enrichment engine module builds an XML document merging data coming from the sensor network. For each measure, this document contains the next attributes: `SENSOR_TYPE`, `PARAMETER`, `CURRENT_VALUE` and `UNITS`. After that, this document can be delivered to the PSAP at any time.

The next section will describe the interaction model and the eCall+ establishment sequence.

A. Emergency call establishment sequence

The environment monitoring module decides whether the eCall+ can be started or not basing on the quality of the UMTS link and the negotiated AV parameters. Whenever any of those parameters are not sufficient for establishing the eCall+, the OAM will be activated with a message thru the RS-232 channel and it will execute the basic emergency call.

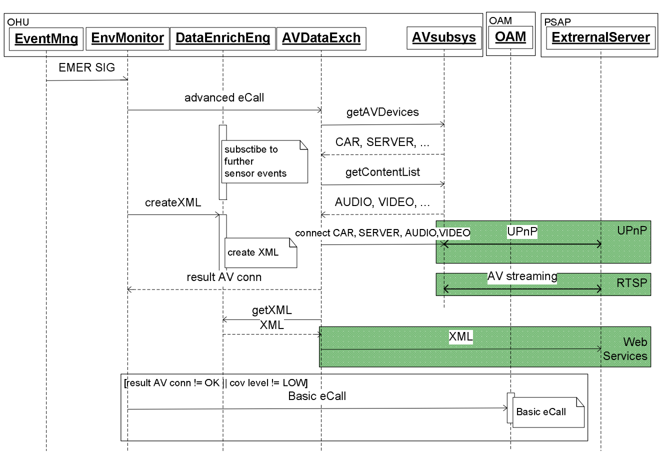

Figure 2. eCall+ sequence diagram.

Figure 2 shows how the videoconference and data connections with the external server are established. In the first case, the negotiation consists of selecting a source and a destination for each component of the videoconference (audio and video). The available devices can be obtained invoking the appropriate AV UPnP services. Then, a new RTSP streaming channel is opened for each of these pairs. In the second case, the sensed data is obtained on the PSAP server demand, via Web Services. The OHU is always ready to send the XML document that the data enrichment engine service builds and updates in real-time since the eCall+ is triggered.

B. Telecommunication infraestrucutre

CALM, Continuous Air Interface for Long and Medium range [11] is an initiative by the ISO TC 204 Working Group 16 to define a standardized set of air interface protocols for medium and long range high speed Intelligent Transport Systems communication with multipoint and networking protocols that enable data transferences between different nodes.

The eCall+ telecommunication architecture (see Figure 3) is defined taking CALM as a reference. Also it is based on the ABC (Always Best Connected) philosophy, so it tries to provide the best connection to the services built on top.

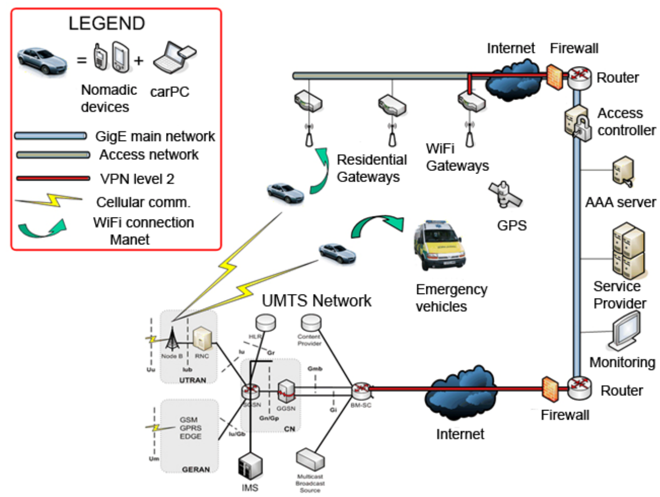

Figure 3. Telecommunication architecture.

The core of the communications software in the car-gateway is the transparent connectivity layer (see Figure 1). It manages both the internal and external car communication. Inside the vehicle, a private LAN will be built, to communicate different devices (sensors, nomadic devices like PDAs, cell phones, etc.) with the car-gateway using short range communications (Bluetooth, WiFi and Zigbee).

The goal of the external communication system is to allow seamless (without user intervention) mobility of data between the car and external nodes. The system combines two kinds of communication, short and long range ones keeping a transparent handover between them. This implies avoiding packet loss by mean of buffering mechanisms.

The short range communications is supported by the 802.11 protocols family, in particular the 802.11b/g module. IEEE 802.11, initially designed for in-house applications, nowadays is a widely used set of standards for WLAN communications. Nevertheless new protocols are in-process to cover new environments, i.e. the future 802.11p standard designed for vehicle-to-vehicle communication.

Also another WiFi interface in ad-hoc mode supports the long range communications. Wireless ad-hoc networks in vehicular environments are known as VANETs. This form of Mobile ad-hoc network provides communications among nearby vehicles and between them and nearby fixed equipment (roadside equipment). A VANET is composed of self-configuring mobile clients forming an arbitrary topology that may change rapidly and unpredictably because the nodes are free to move randomly and organize themselves arbitrarily. The AODV (Ad-hoc On-demand Distance Vector) protocol is in charge of routing data packets in this context. Routing in this kind of networks is not totally solved, since there is not a unique protocol that could afford the best performance in all the scenarios. The eCall+ communications architecture adds the UMTS back up channel to the standard implementation. The system makes a decision about switching among them according to the state-of-the-link information retrieved from a link monitoring process.

Also a mechanism to provide priority-based QoS is defined by means of signaling packets with higher priority for accessing the medium.

V. On-Board Auxiliary Module (OAM)

The OAM is a double function element in the car-gateway. On the one hand, it is a GPS receiver responsible for calculating the car position, the altitude and the speed. On the other hand it is a backup element able to withstand high impacts. Thus, it guarantees the emergency call even in case of critical crashes. To provide this backup function the OAM continuously monitors the OHU and takes over whether it fails. In this case, the OAM establishes a direct communication to the external server reporting the position and performing the basic eCall if it is required.

A. Internal architecture and telecommunication infraestructure

Figure 4 shows the OAM architecture. OAM is composed of the following modules:

- Integrated **GPS-receiver**. This module uses data from the satellites to calculate the exact position of the vehicle. These data are received using the GPS signal. GPS is the well-known radio navigation system funded and controlled by the U.S. Department of Defense.

- **GSM/GPRS modem**. The modem tries to register itself into the GSM network to establish the basic emergency call or to communicate the vehicle position and events when the OHU fails. For that, the GPRS (General Packet Radio Service) system is used. GPRS is a packet oriented mobile data service available to GSM (Global System for Mobile) users. The GSM system is used to establish the basic eCall. GSM is a standard for mobile phones that consists of a cellular network, operating in four different frequency ranges and allows the users to access different services at once.

- **Microcontroller**. It implements the logic that processes the position from the GPS data and delivers it to the external server. Before starting the basic emergency call, the microcontroller tries to talk to the OHU sending periodic keep-alive messages through a RS-232 channel. If any response is received, the OAM starts a GPRS connection to the external server. This module is also able to handle the basic emergency call communication via GSM (just voice).

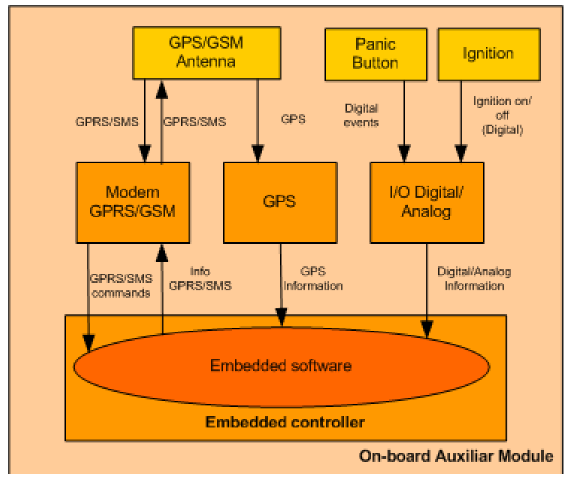

Figure 4: Internal OAM architecture

- An **I/O module**. It is responsible for analyzing both digital and analog inputs. It also synthesizes the digital signal in case the embedded software requires this behavior.

B. Data exchange

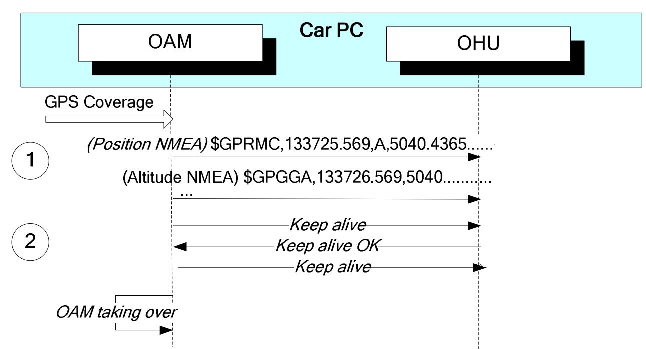

Figure 5 Data exchange between OHU and OAM

The OAM data exchange with the OHU (see Figure 5) takes place at two levels:

- **GPS data**: The position data is turned into latitude and longitude coordinates, usually provided in the native GPS geodetic datum (WGS84). Then, they are transmitted via TCP to the PSAP using National

Marine Electronics Association (NMEA) sentences. These GPS data are based on the following NMEA standard messages [12]:

GPGGA GPS Fix Data
GPRMC Recommended Minimum Specific GPS Data
GPGSV GPS Satellites in View
GPGSA GPS DOP and Active Satellites
GPVTG Course Over Ground and Ground Speed
GPGLL Geographic Position in Latitude/Longitude.
GPIOP OAM Input/Output Ports

- **OHU status**: The OAM is continuously monitoring the OHU status by means of periodic keep-alive messages. The OAM waits for the OHU ACK response. After a few ACKs are not received the OAM takes the control to guarantee at least the basic eCall.

The data exchanged between the OAM and the external server (see Figure 6) can be divided in three groups:

- **GPS data**: The OAM is analyzing continuously the OHU and when it detects that the OHU is not working the OAM takes over and sends all these GPS data directly to the PSAP.

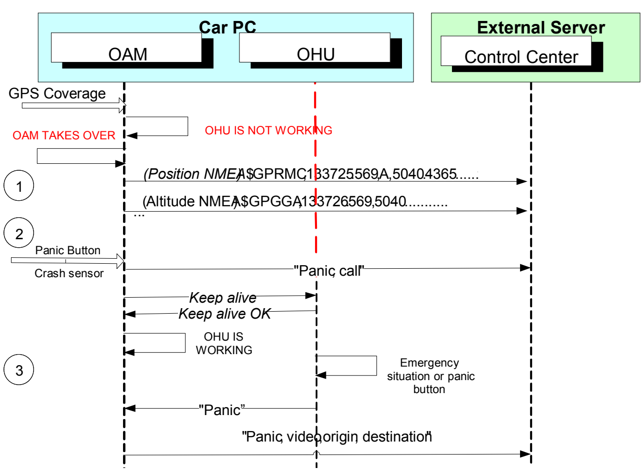

Figure 6. Data exchange between the OAM and the external server

- **Panic event**: When the user detects a panic situation, he pushes the panic button and then the OAM informs the PSAP about this event using the message `PANIC, CALL`.
- **Emergency situation event**: The OHU sends the message `PANIC` to the OAM when the OHU is working correctly and an emergency situation occurs. The OAM forwards this event to the external server to establish a streaming session from the assistant terminal to the car-gateway and it starts the eCall+.

VI. EXTERNAL SERVER

The architecture component on the PSAP side is the external server. It is composed of two different servers: the control center and the streaming server.

The first one is responsible for analyzing the information provided by the car-gateway in order to show the position and tracking of the vehicle as well as the alarm events into a map. The streaming server receives the order to establish a streaming session from the car-gateway to the final destination. Additionally this element provides a black box function to reproduce the circumstances previously to a specific moment of the accident. It also manages location-based services. Since it is integrated in TomTom[4] it is possible to provide the driver with information about the nearest service station, hospital, points of information, etc.

Finally this element can warn to the hospital and the police about the accident and its location. It can also search the nearest ambulances, police vehicles, etc.

VII. EXPERIMENTAL RESULTS

The first prototype considers a scenario where only the OAM is working. The ongoing functional demonstrator includes both the OHU and the OAM working together.

The prototype consists of a briefcase with the following installation: the OAM, led indicators for status control, a panic button, an ignition button, GPS and GPRS antennas, a speaker and a microphone.

The OAM embeds Quad Band GSM/GPRS core, high-sensitivity 20-channel GPS core, 3D-motion sensor and a rechargeable 1100 mA/h Li-Polymer battery. This battery provides continuous operation for about 10-12 hour if the external power source fails. The OAM has two digital inputs (the car's ignition and the panic button) and several digital outputs. The integrated audio channel allows voice communication.

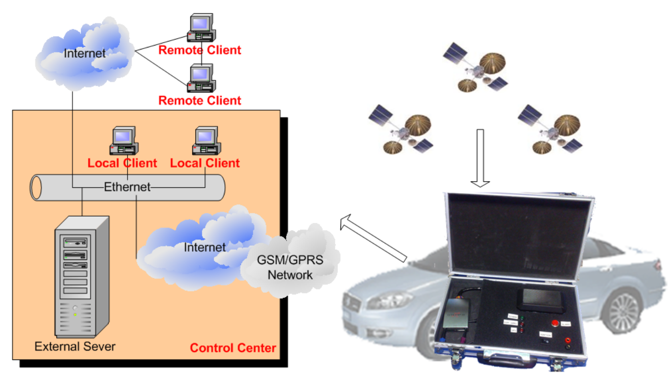

Figure 7. Testing platform

The OAM connects to a preselected PSAP located in an external server (a conventional PC connected to the Internet). This server runs some web applications based on the Kyros proprietary control center that has been adapted to the requirements of the eCall+ application. These applications are published through a HTTP server. Any web browser can connect to the PSAP from any other node and access the emergency applications (monitoring, tracking, etc.) From the car, the eCall is activated pushing the panic button. Once an

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[4] The well-known automotive navigation system.

error in the OHU is detected, the OAM initiates the basic eCall and immediately dispatches an alarm to the PSAP.

An assistant, with the help of his web-browser, can check the position of the car, the tracking as well as the resources nearby the car such as police, ambulances, hospital, etc. Figure 8 shows the GUI of the web-based PSAP application; a powerful tool resulting from combining the OAM information with some GIS (Geographic Information Systems) as Google Maps. In the next prototype the alarm will not be only triggered by the panic button but also by the OHU automatic detection engine. The whole testing platform is shown in the Figure 7.

There is an available demo application in the web[5] that provides access to the PSAP web application. As you could check, it is a simple, user-friendly interface (Figure 8) that allows the assistants a fast diagnostic based on the current and historic tracking and real time alerts.

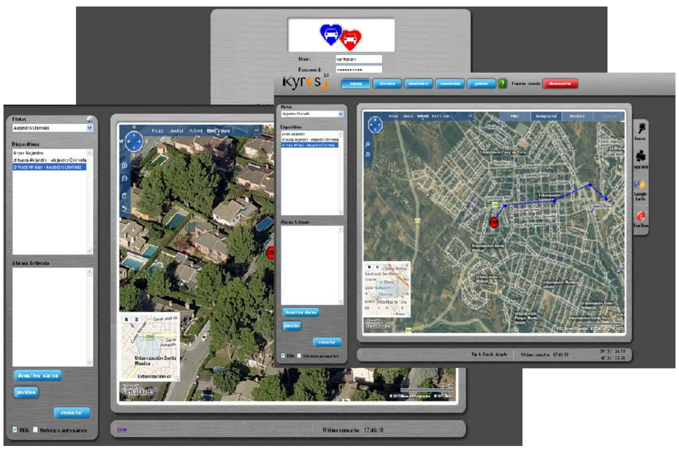

Figure 8. The PSAP web application shows the crashed car location and tracking

VIII. CONCLUSIONS

An advanced concept of emergency call, the eCall+ and the supporting architecture has been described along this paper. Ancient communication technologies have been substituted by most advanced, wide-used ones like UMTS and WiFi in order to support ambitious safety applications like multimedia exchange, real-time data dispatching and videoconference. High compatibility with Internet communication protocols and network services characterize the proposed architecture, which is easily extensible for supporting current and coming emergency services. A dual on-board unit guarantees the reliability against accidents, a central objective along the design process. A detailed discussion of the first prototype can be used as a proof of concept.

Next steps in this research are mainly the completion of the prototype, the improvement of the dual unit and supporting architecture, enhanced data compilation algorithms, protocol revision and finally, the implementation and integration of new safety applications.

ACKNOWLEDGMENT

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