ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 10, April 2015

Testing of an IVS prototype for the eCall system under the European HeERO2 project and analysis of the results from the jointly tests with 112 emergency call center

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***Abstract*— HeERO is a European project aimed at introducing and implementing the innovative eCall system which is designed to lower the severity of car crashes by reducing the rescue forces' response time. As the system is still in a pilot phase, tests have to be done to evaluate and prove the real-life readiness of eCall. This paper presents the Technical university of Sofia's prototype of an eCall In-vehicle system device (IVS) and the results of the tests made with it. The analysis shows that all parameters are well within the target range, thus showing that the Bulgarian pilot site meets all requirements of the HeERO project and the eCall system is ready for real-life application.**

Index Terms— **eCall, HeERO, IVS, testing, prototype.**

I. INTRODUCTION

Despite the economic crisis in recent years in the EU the automotive industry continues its growth, reaching 16.2 million new vehicles for 2013, of which more than 13 million are already on the roads [1]. To meet the increasing risk of road accidents, car makers and various organizations introduce different measures for reducing the number and severity of crashes. One such measure is the implementation of the innovative eCall system [2] until 2017, under the HeERO, HeERO2 and I_HeERO European projects [3]. The projects cover pilot realizations in over 15 EU countries, including Bulgaria. This paper covers HeERO2 and eCall system characteristics, the Bulgarian pilot specifics and the features of the Technical University of Sofia's prototype of an In-vehicle system device (IVS), implementing their own minimum-set-of-data (MSD) encoding [4]. Bulgaria's national eCall chain performance test results and analysis are presented as well as a comparison between HeERO2 participating countries.

II. THE HEERO2 PROJECT

HeERO is an EU project, under the management of ERTICO – ITS Europe. Its goal is the implementation of the pan European eCall system in all new cars and the creation of the necessary standards and legislation until 2017 [3]. In the first part of the project – from 2011 to 2013, the nine participating countries fulfilled the goal of making their own eCall pilot realizations so well, that the project got an extension – HeERO2. In this second part – from 2013 to 2015, six new countries took part, including Bulgaria [5]. The Technical University of Sofia (TUS) participates as a partner in the Bulgarian consortium, alongside the Ministry of Interior, 112 Emergency Centre, Bulgarian Association ITS and others. During the project TUS designed and constructed its own of an eCall IVS device. The resulting prototype was so good that it was used for the national eCall chain tests. In addition it was used to perform interoperability tests with foreign 112 centers from other HeERO and HeERO2 countries.

The HeERO projects define the so called Key Points of Interest (KPI) [6]. These are the parameters to be monitored and recorded by IVSs and 112 centers for every country's pilot tests. The parameters are chosen by ERTICO in a manner that their analysis would allow to estimate the workability of each separate module as well as the operational capacity of the eCall chain as a whole for each pilot site. As the eCall standards are still under development, another purpose of the KPIs is to estimate the relevance of the definitions and limits for different parameters, given in these standards. Some of the KPI parameters are: Number of automatically/manually initiated eCalls, Success rate of completed eCalls using 112, Success rate of received MSDs, Duration of voice channel blocking (MSD send time), etc.

III. THE ECALL SYSTEM

The main goal of the eCall system is to lower the severity of damages caused in road crashes. To achieve that the system focuses on shortening the reaction time of rescue forces, through automatic on-time signalization to the 112 center and sending of critical data, including exact accident location, as shown on Fig. 1.

The eCall system comprises of two main modules:

- In-vehicle system device – installed in the vehicle, the device continuously monitors the airbag deployment and then automatically calls the 112 emergency numbers, sending critical MSD data.
- eCall compliant 112 centers (PSAP) – accepts the call,

ISSN: 2277-3754
ISO 9001:2008 Certified
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decodes the data and visualizes it on the operator screen.

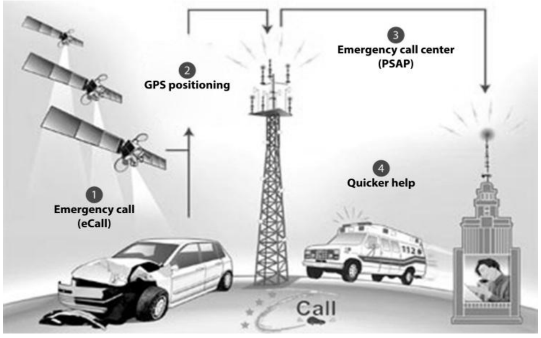

Fig. 1 The eCall chain

According to the EN15722 standard [7], the data sent to the PSAP is: VIN number of the vehicle; engine fuel type, timestamp and GPS positioning of the crash site, vehicle direction of travel, 2 previous positions of the car and passenger count, if available. This data forms a packet of 140 bytes, called a Minimum set of data (MSD), encoded in a standardized ASN.1 scheme. The data is run through an InBand Modem, implementing a state-of-the-art modulation [8] and sent over the voice channel of a 2G GSM network. To distinguish the type of emergency – manually triggered eCall or automatically sensed crash, all eCalls are flagged in the network operator with an 'eCall flag', allowing routing with different priorities to the 112 center. The normal sequence of an eCall is shown on Fig. 2.

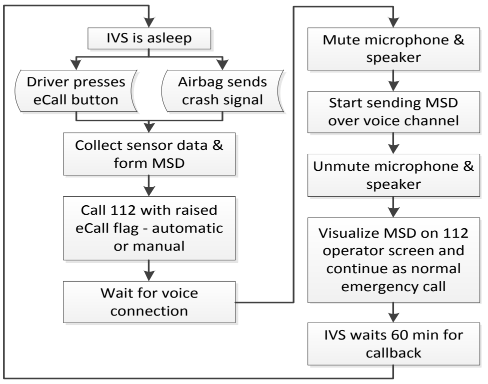

Fig. 2 Normal eCall workflow

The statistic shows that implementing the eCall system shortens the rescue forces' response time with 60% for urban and with 50% for non-urban areas. Nonetheless the TUS team considers the biggest impact of the system to be the automatic signaling of severe accidents that take place in remote areas with no witnesses, in the case where passengers are not able to call 112 themselves.

IV. TECHNICAL UNIVESITY OF SOFIA'S IVS DEVICE

The functions of an IVS device include GPS positioning, GSM calling, sensor data processing, triggering on external signals, etc. Fig. 3 shows a basic structure of a real-life IVS that would allow for these operations to be performed.

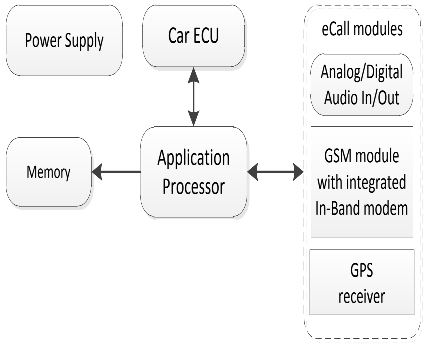

Fig.3 Basic structure of a real-life IVS device

As a HeERO2 partner, TUS' purpose was to design and construct an IVS device, to be used in various tests, assessing the Bulgarian eCall performance and quality, and mostly the PSAP upgrade of the 112 center's PBX. This implies performing additional tasks, like carrying out a large number of eCalls, data logs recording, etc. This is why the IVS structure of the Technical University of Sofia's prototype, shown on Fig. 4 is slightly different.

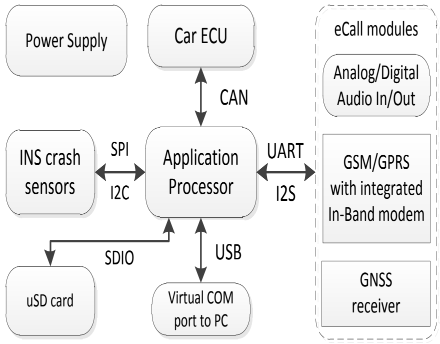

Fig.4 Structure of TUS's IVS prototype

As can be seen a few additions were made to the basic structure from Fig. 3 – a PC connection module (Virtual COM port) and a module with inertial sensors that allows the IVS to perform self-triggering using IEEE1616 methods [9] without airbag signal dependency. As the figures show, the most important part of the device is the application processor, which commands all other modules. All tasks that the IVS needs to perform are implemented in its firmware. But to develop an IVS source code for a microcontroller would take times longer than developing PC targeted software, which implements the same algorithms. Taking into consideration the tight schedule of the project, the TUS team chose the second approach. To perform all tests the IVS board is controlled from custom built software, sending AT commands through a virtual COM port to the microcontroller, which in turn retransmits them to the other modules, when needed. The software, called G100 Wizard, incorporates all needed functions to perform the necessary HeERO2 tests. A screenshot of the software is shown on Fig. 5.

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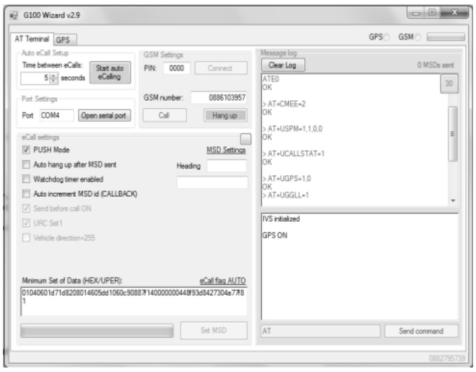

Fig.5 G100 Wizard – IVS controlling software

The software's functions include initialization of the COM port and the IVS device (SIM unlock and mode select, GSM and GPS modems initialization, etc.), eCalling, event logging, etc. By pressing the 'Start auto eCalling' button all operations are performed fully automatically at a predefined interval, which allows for more tests to be conducted. The software works out and logs nearly all warning and error messages by itself, allowing nearly no need of operator attention. As most of the warnings and errors are linked to low or no GSM/GPS signal coverage, the data collected allows for a better analysis of the unsuccessful eCalls. This helps to define the limits of the IVS' performance in remote areas and mountain terrains.

To further improve the qualities of the IVS, instead of the standard ASN.1 encoding, the G100 Wizard implements a custom MSD encoding scheme, developed by the TUS team [4]. It is faster and requires fewer resources from the microcontroller to run. The high performance of the IVS and the successful communication with the PSAP proves that this alternative approach is working and fully compatible with the standard EN15722 ASN.1 encoding.

V. TEST SETUP AND RESULTS

The test setup of the Technical University of Sofia, with which all official tests are made comprises of the IVS prototype, installed in a passenger car, connected through USB to a notebook computer, with installed G100 Wizard. The GSM and GPS antennas are mounted on the car roof for better signal coverage, the audio connection is through a handsfree and the power supply is connected to the car's cigarette lighter. As the purpose of the tests is to perform maximum number of eCalls in similar conditions, the 112 center PBX is also configured with a test oriented temporary setup, which allows it to work without operator intervention. When an eCall is received, the PBX automatically answers and starts MSD transmission. When the data is received voice connection is simulated by playing a recorded message. The G100 Wizard is programmed to automatically recognize this voice message and react accordingly. In this way the driver of the car is not obligated to even use the handsfree to monitor the correctness of the tests. All national tests were made using the described test setup in three test sessions for a total of 10 days, while driving in all major cities and main roads of Bulgaria. After the test completion data from the IVS and PSAP logs were collected and matched to produce the final KPI results for Bulgaria, shown in Table 1. The marked KPIs are considered of highest importance according to ERTICO and are mandatory, as the others are mostly optional. The analysis of these results shows that the Bulgarian eCall chain is ready for real-life situations.

Table 1. KPI parameter results from the Bulgarian HeERO2 pilot tests

Signature	Name of KPI	Result	Unit
KPI_001a	Number of automatically initiated eCalls	1 609	-
KPI_001b	Number of manually initiated eCalls	1 074	-
KPI_002a	Success rate of completed eCalls using 112	92,77	%
KPI_002b	Success rate of completed eCalls using long number	84,92	%
KPI_003	Success rate of received MSDs	92,77	%
KPI_004	Success rate of correct MSDs	100	%
KPI_005	Duration until MSD is presented in PSAP	11	s
KPI_006	Success rate of established voice transmissions	98,06	%
KPI_007a	Duration of voice channel blocking	5	s
KPI_007b	Duration of voice channel blocking: automatic retransmission of MSD	5	s
KPI_008	Time for call establishment	4	s
KPI_009	Accuracy of position	acceptable	
KPI_010	Number of usable satellites	10	-
KPI_011	Geometric dilution of precision	1,37	-
KPI_012	Time between successful positioning fixes	1	s
KPI_013	Success rate of heading information	100	%
KPI_014	Success rate of VIN decoding without EUCARIS	100	%
KPI_015	Success rate of VIN decoding with EUCARIS	n/a	%
KPI_021	Number of successful call-backs	92	-
KPI_022	Success rate of call-backs	100	%
KPI_023	GSM network latency	<3	s
KPI_024	112 national network latency	<1	s
KPI_025	112 operator reaction time	2,535	s
KPI_026	Time for acknowledgement of emergency services	n/a	s
KPI_027	Total response time	n/a	s
KPI_028 a	Number of cross-border tests	n/a	-
KPI_028 b	Number of interoperability tests	104	-
KPI_028 c	Number of cross regional tests	n/a	-

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ISO 9001:2008 Certified
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Table 2. Comparison between KPI results from HeERO2 countries

KPI\Country	Belgium		Bulgaria		Luxembourg		Turkey		Denmark		Spain	
KPI_001a	0	-	**1 609**	-	0	-	0	-	0	-	421	-
KPI_001b	532	-	**1 074**	-	743	-	969	-	185	-	410	-
KPI_002a	77,05	%	92,76	%	-	%	**98,00**	%	-	%	-	%
KPI_002b	77,05	%	84,91	%	82,23	%	-	%	**94,00**	%	80,76	%
KPI_003	73,30	%	92,76	%	67,71	%	98,00	%	**99,00**	%	82,04	%
KPI_004	73,30	%	**100,00**	%	**100,00**	%	99,00	%	**100,00**	%	95,70	%
KPI_005	-	s	**11,00**	s	12,29	s	35,00	s	13,60	s	19,36	s
KPI_006	-	%	**98,06**	%	97,58	%	98,00	%	95,00	%	85,48	%
KPI_007a	13,00	s	**5,00**	s	9,90	s	7,00	s	9,90	s	10,64	s

The parameters achieved with TUS' IVS prototype exceed the expectations and are among the best within the entire HeERO2 project. To confirm that Table 2 shows a comparison between KPIs for the HeERO2 countries – Belgium, Bulgaria, Luxembourg, Turkey, Denmark and Spain. The missing values are the KPIs that each country failed to collect. With bold on Table 2 are shown the best achieved values. It can be seen that Bulgaria has one of the best results. Thanks to the entirely automated testing chain the highest number of tests were made – 2683. Implementing the custom MSD encoding scheme in TUS' IVS prototype the average MSD send time is the lowest – 5 seconds. Denmark has the highest call success rate for long number dialing, but this is due to the mainly flat country terrain and better developed road and mobile network infrastructure. Still, although 50% of the tests in Bulgaria were made in non-urban and mountain terrain, the average success rate is still over 92%. In addition 19 interoperability tests were made with TUS' prototype, verifying the compatibility between the IVS and the PSAPs in Greece, Croatia and Romania. For performing the tests the eCalls were made, dialing the long international number of the respective 112 center, while the IVS remains on Bulgarian territory. The test reached over 90% success rate with average time of 10 seconds for MSD sending. This shows that the systems are fully compatible and could get even better results if the IVS device is on the respective country's territory dialing directly the 112 number.

VI. CONCLUSION

This article presents the Technical university of Sofia's solution for a prototype of an IVS device used to perform the Bulgarian eCall tests under the HeERO2 pilot project. TUS' specific structure and settings of the device allow for a large amount of tests to be carried out with little to none operator intervention, while driving a test vehicle across the country. Replacing the standard ASN.1 [7] encoding with TUS' custom approach [4] shortens the overall time for packing and sending the MSD to the 112 PSAP center. The results are more than satisfactory, as stated in ERTICO's final project report [10]. The achieved parameters for the eCall implementation in Bulgaria are one of the best among all HeERO and HeERO2 countries. All of this comes to show that the Technical University of Sofia is ready for the next step - implementing the IVS as a real-life device. Going even further would be to integrate the IVS as a part of a larger fleet management system. This idea has already been researched by the team and is in development process.

VII. ACKNOWLEDGEMENT

This article was financed by the Technical university of Sofia's Faculty of Mechanical Engineering, Department Fundamentals and technical means of design.

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