Section 2. RT (Internet of Things, Real-Time Systems).

UDC 004.8

Anna Bezverkhnia, Artem Volokyta.

ISSUES IN WORLDWIDE APPLICABILITY OF AUTOMOTIVE EMERGENCY CALL SYSTEM

This paper deals with the issues of applying an automotive emergency system globally. Technology stack for the system is discussed with comparison of different available technologies, which can be used for development of uniform emergency system regarding of its destination country.

Key words: emergency call system, vehicle, Public safety answering point.

Fig.: 3. Tabl.: 3. Bibl.: 17.

Urgency of the research. According to the research in correlation between emergency medical services (EMS) response time and traffic accident mortality, the motor vehicle collisions (MVC) mortality rate was twice as high in counties with median EMS response times ≥12 minutes compared to those with <7-minute response times. It was estimated that reducing response times to <7 minutes in urban/suburban counties and to <10 minutes in rural/wilderness areas could have prevented 13% of all MVC- related fatalities. [1]

In order to reduce the collision emergency response time, EU developed emergency call system for vehicles called eCall and made it mandatory in all new automobiles sold within the EU from April 2018. It is estimated that eCall cuts emergency services' response time by 50% in rural and 40% in urban areas.[2] Meanwhile, since January 2017 all vehicles that are put into circulation throughout the territory of the Eurasian Customs Union (including Russia, Kazakhstan and Belarus) have to be equipped with the ERA-GLONASS emergency calling system developed by Russia.

Target setting. There is no uniform standard for automotive emergency call system applicable for all countries. In some regions that is handle only by privet companies. In order to make automotive emergency call system available and used in all countries, it should fit to the worldwide requirements.

Actual scientific researches and issues analysis. Emergency call system out of EU provided by private market. As an example, there is Uconnect [3] emergency assistance, which can call 911 operator and OnStar [4] emergency service which can provide indirect emergency services through OnStar adviser. However, their implementation details are unknown and services can operate only on US territory. Main source of researches is open documentation of European emergency call system, eCall, which specify its requirements, features and deployment. [5]

Uninvestigated parts of general matters defining. The aim of the article is to analyze possibility of creating uniform emergency call system suitable for all countries without significant modernizations. That system should provide direct access to Public Safety Answering Point (PSAP) and do not depend on any privet services.

The research objective. Develop technological stack of automotive emergency call system suitable for any country.

The statement of basic materials. The analysis of uniform technological stack for emergency call system is conducted. Worldwide acceptable technologies are proposed. The results of analysis show some solutions and concerns in uniform emergency call system global deployment.

Use case overview. An emergency situation includes three actors: the emergency call system, PSAP and emergency services. An expected action flow is depicted on Fig. 1. A vehicle emergency situation should trigger an emergency signal of the system which in turn starts the emergency action flow. Emergency signal can be triggered either manually by user or automatically based on vehicle system data analysis. As soon as emergency situation detected, the system gets information about current location and form it in MSD together with other valuable data stored in the system. Then system transmit MSD and conduct a voice call to PSAP. PSAP operator conduct a call to specific emergency services based on provided information. Emergency services in turn carry on the rescue operation.

System requirements. Before investigation of technologies suitable for automotive emergency call system we should determine which requirements have to be met.

Basic requirements:

- Collision detection
- Manual emergency signalization
- Damage protection
- Reserve energy supply
- Location detection
- Transfer of Minimum Set of Data (MSD) to PSAP
- Voice connection to PSAP
- Memory storage
- Ability to cancel the call in case it was triggered accidentally
- Privacy
- Way to flash default information

Concepts listed above will be explained one by one in order to broaden the understanding.

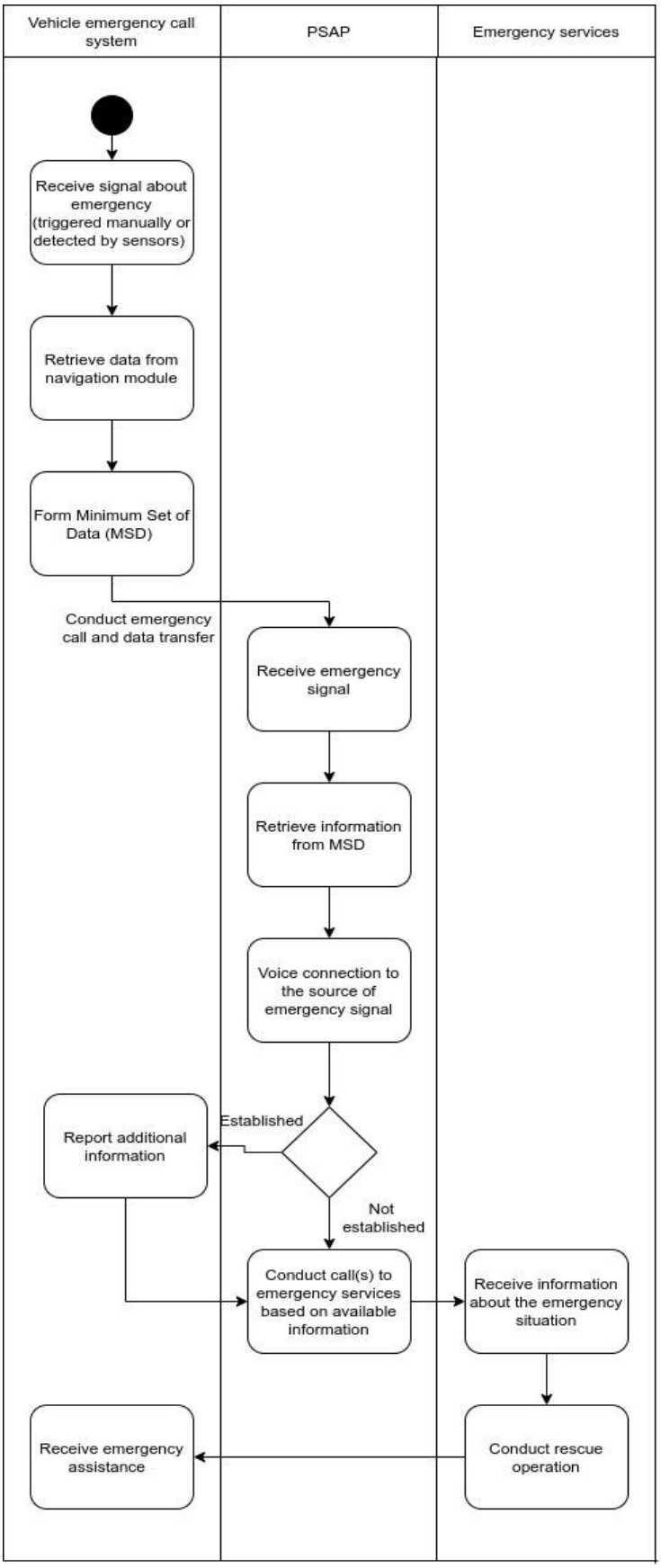

Fig. 1. Emergency action flow

Collision detection. The system should be able to detect that the collision occurred. That mean it should monitor conditions of car systems as well as its integrity.

Manual emergency signalization. The user should be able to trigger emergency call manually in case of emergencies that cannot be handled by the system. For example, inappropriate medical condition of passenger or witness of emergency with another vehicle.

Damage protection. In case of collision the vehicle can be significantly damaged, so the systems must ensure high resistant hardware protection from physical damages in order to continue proper operation.

Reserve energy supply. The main power source of all vehicle systems is an automotive battery, but during the collision it could be damaged or disconnected. Hence, the system should be supplied with additional energy source in order to insure work after the accident.

Location detection. Vehicle location should be transmitted to PSAP by the system in order vehicle to be found by emergency service.

Transfer of Minimum Set of Data (MSD) to PSAP. In order to give more accurate information about the collision, the system should send basic technical information about the vehicle, like type and maximum number of passengers; data about vehicle owner, like name and age; and vehicle location data. That data formed in MSD and send to PSAP as the first priority.

Voice connection to PSAP. The system itself can send only the basic information like location, so additional important information can be provided by user through the voice communication to PSAP assistant.

Memory storage. The system should have both volatile and non-volatile memory. Volatile memory of the system is used during operations, while non-volatile holds constant data like vehicle information and emergency phone number.

Ability to cancel the call in case it was triggered accidentally. The system SOS button needs to be accessed and used easily in order to provide quick response. However, at the same time that mean that it can be pushed easily accidentally as well. Consequently, system should provide sufficient way to cancel the call.

Privacy. Vehicle information and location data can be used by attacker, so the system should receive and send the data only when emergency situation occurred.

Way to flash default information. As the system designed to be uniform, it should provide a way to be filled with differentiated (specific) information. The vehicle service provider should flesh an information about emergency service phone number, vehicle type and owner info as the vehicle is sold.

Components overview. In order to determine the most suitable technologies for the uniform automotive emergency call system, system components need to be

chosen. Based on requirements, the following hardware components can be determined:

- CPU
- Sensors
- Power supply
- Communication module
- Navigation module
- Audio input/output
- Memory
- Protection suit
- Hardware buttons

Description:

CPU. Manages all system operations.

Sensors. Detect vehicle condition.

Power supply. Reserve energy supply in case of energy supplying termination from main vehicle battery.

Communication module. Module that is used for audio and data transfer. Depends on selected technology.

Navigation module. Module that is responsible for collecting data about current vehicle position during emergency. Depends on selected technology.

Audio input/output. Used during audio communication with PSAP.

Memory. Used to store constant data and real-time processes data.

Protection suit. Protect sensitive hardware from damage.

Hardware buttons. Buttons which are placed on driver panel in order to trigger or cancel emergency service call manually.

Simplified system structure can be found in Fig. 2.

Technologies selection. The system as a whole consists of set of technologies, which are combined. Some technologies are common to any automotive emergency call system implementation, while other depends. This section is aimed to describe common technologies and make comparison of those, that can vary. However, it does not deepen in common technologies as the crucial role in systems unification play those technologies which should be selected from a range of similar ones.

1. *Common technologies*.

1.1. *Real-time operating system*. The main part of the vehicle emergency call system is CPU and a system that operates on it, because it manages all the peripherals and emergency actions. Simplified concept of system routine described on Fig. 3. However, this routine also can be interrupted by button pressing, which starts or cancels emergency call operations.

In order to implement such a mechanism on embedded systems, *Real-time operating system* (RTOS)[6] is used.

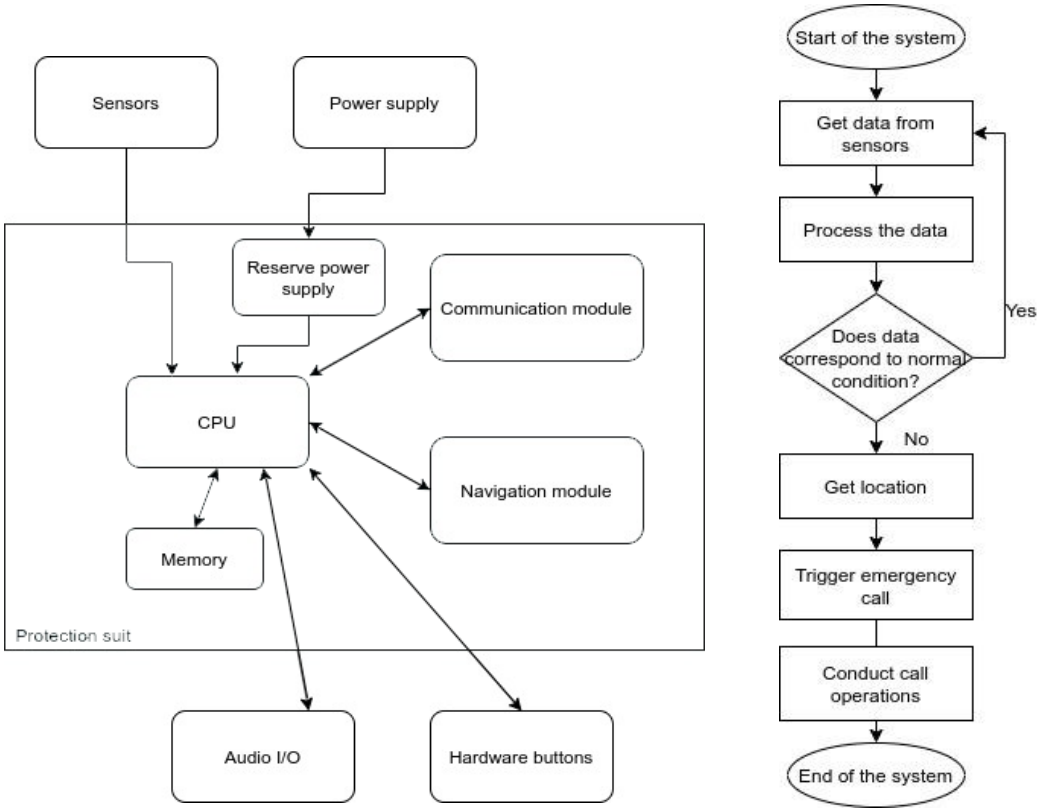

Fig. 2. Simplified system structure. Fig. 3. Simplified system routine

1.2. *Memory*. In order to maintain RTOS, the system should have RAM and ROM memory. The size of memory highly depends on RTOS implementation and CPU architecture. Moreover, the size of permanent data that is used for PSAP information should be taken into account while determining the size of ROM.

1.3. *Audio*. Most of the vehicles have built in audio input/output, so the system can be connected to them without own audio IO. However, the collision may cause a damage to vehicle standard audio IO, that mean that the system will be cut of any audio interfaces. Hence, it is more reliable to have separate microphone and speaker for the emergency system. Moreover, it is better to keep the emergency call system as thing in itself in order to reduce an interference with other systems of the vehicle.

1.4 *Sensors*. Motor vehicles already have special crash detection sensors that, for example, are used to activate an airbag. Signal from the same sensors can be used for collision detection in the emergency call system. However, that cause an interference with another system of a vehicle. That makes a deployment of emergency system more complicated. In modern automobile data transfer conducted through the different vehicle systems by means of CAN protocol [7], so CAN protocol implementation will be needed in order to receive data from sensors.

2. *Varied technologies*.

2.1. *Communication.* Communication technology of the system should meet some requirements, which are linked to conditions of the usage.

Table 1.

Technology requirements based on usage conditions

System usage condition	Technology requirement
The system should not depend on region of usage	Global reached
The system should be capable of conducting emergency call regarding of an area: urban/suburban/rural/wilderness	High quality coverage
Communication through the system should be available for any user	Free to use for emergencies
Vehicles can be used for more than 10 years and system should still be able to conduct calls without hardware upgrades	Future proofness
In normal conditions system has constant source of power, in case of vehicle battery damage it is supplied from its own reserved battery.	Power consumption is not an issue
In case of emergency the system transfer audio and text to PSAP	High data rate
Data from the system is sent to PSAP in one direction, while audio communication take place for both sides	Bidirectional

Communication technologies [8] are available in three major groups:

- Short range technologies
- Low Power Wide Area (LPWA)
- Traditional cellular

Their comparison can be found in Table 2.

Parameters of different communication technologies were marked grey as not acceptable by the emergency call system. Target technology should meet all the requirements listed in Table 1. As a result, we see that two technologies are acceptable based on basic feature comparison: LTE-M [9] and LTE [10]. LTE (Long Term Evolution) technology known as 4G, while LTE-M is its low power version for machine to machine (M2M) communication. However, LTE-M technology does not as spread as LTE, because it requires extra effort in deployment. Currently, LTE-M does not available in Africa, Middle East and Asia, while LTE does. In 2019 the lowest 4G coverage was 49.9 percent (in Uzbekistan), while the highest was 97.5 percent for South Korea [11]. Providing the better coverage of 4G technology is a global tendency now, so we can rely on LTE as on the technology which will provide worldwide coverage for long period of time.

As for hardware support of LTE technology, the system should include the following units:

- *LTE modem*
- *Embedded SIM*
- *Antenna*

Table 2.

Comparison of technologies by basic features

Considerations	Short range technologies		Low Power Wide Area (LPWA)				Traditional cellular		
			Cellular		Proprietary				
	Bluetooth	**Wi-Fi low power**	**SigFox**	**LoRa**	**NB-IoT**	**LTE-M**	**2G**	**3G**	**4G**
Outdoor coverage	<100m	< 1km	>15km	>10km	>15km	>10km	>10km	>10km	>10km
Typical uplink data rate	1 Mbps	1 Mbps	100 bps	25 kbps	20 kbps	1 Mbps	50 kbps	1 Mbps	10 Mbps
Bidirectional communication	Yes	Yes	Limited downlink	Only Class A	Yes	Yes	Yes	Yes	Yes
Future proofness	High	Medium	Low	High	High	High	Medium	Medium	Very High
Global reach	High	High	Medium	Low	High	High	Very high	Very high	Very high
Quality of Service	Medium	Medium	Very Low	Low	High	Very high	Very high	Very high	Very high

LTE modem provides 4G connectivity as well as Short Message Services (SMS) needed for communication with PSAP. *Embedded SIM* (subscriber identification module) is a reprogrammable SIM card that is used to identify and authenticate subscriber on the network. *Antenna* covers an electric signal to the radio and vice versa in order to transmit and receive data. Antenna should have a specific size and shape for producing and receiving specific frequencies of radio waves compatible with LTE operating frequencies.

2.2. *Navigation Satellite Systems.* Navigation Satellite System is the source of information about geographical location of the object. Actually, operating systems can be found in Table 3.

Table 3.

Navigation Satellite Systems

Considerations	Global Navigation Satellite Systems (GNSS)				Regional Navigation Satellite Systems	
	Global Positioning System (GPS) [12]	**GLONASS [13]**	**Galileo [14]**	**BeiDou [15]**	**QZSS [16]**	**IRNSS [17]**
Owner	US	Russia	EU	China	Japan	India
Operating territory	Global	Global	Global	Global	Asia-Pacific	India + 1500 km
First launch	1978	1982	2011	2000	2010	2013
Fully operate from	1993	1995	2016	2020 (planned)	2023 (planned)	2020(planned)
Total satellites	33	26	30	35 (2020)	4 (planned 7)	7

Source of location information is one of the biggest issues in terms of unification of automotive emergency call system. In the beginning of 21th century GPS and GLONASS were monopolistic satellite navigation systems. However, in past decades some countries decided to develop their own navigation satellite systems in order to be independent of other countries. That should be taken to account while developing an automotive emergency call system, as different regions want to use different location sources nowadays. Consequently, different hardware and different software should be used for navigation part of the system depending on target region.

Another option of that issue is to use all available navigation systems at once, but that will lead to higher product cost. In terms of device production, the correct way is to produce several types of same system using elements that are specific for regions. However, taking to account that GPS is a time-proved, reliable and worldwide most used GNSS, it can be used as additional or reserved source of navigation information for nearest several years at least.

Concerns. Some unresolved issues in applying uniform vehicle emergency call system still take place, as part of system features need modernization either from PSAP system side or from the side of the vehicle emergency call system for particular country. That causes two issues at the same time. First one is that making significant adjustment in technologies from the side of developed system makes it different for each country, hence, nonuniform, but the target of the research is to develop one system suitable worldwide. Another possible solution of the problem is to keep developed system uniform for all countries, but countries will need to adapt their

PSAP to one uniform worldwide standard. Several issues that causes concerns of that kind are described below.

Messaging. First of all, if system inform PSAP about vehicle location and additional valuable information by some sort of text data (like SMS) then the PSAP system should support that kind of communication.

Free emergency call. In order to provide the uniform vehicle emergency call system worldwide, we need to ensure that the system is capable with policies applied for free emergency call in each country.

No PSAP. Not every country has a generic emergency service like PSAP, as they may use distributed emergency system, when user manually select the emergency service he needs and call directly to that service provider (police, fire, EMS, etc.). That makes it difficult to determine which type of service should be called and is it appropriate to call several services automatically without determining the scale of the disaster.

Conclusions. This article has demonstrated possibilities and concerns in developing uniform emergency call system capable of being applied globally. The generalized system model was developed based on technologies' availability in different countries.

A deeper research in selected technologies interaction and their hardware and software implementation are still needed. Each system should be described more precisely with selection of particular methods for implementation. Also, issues about uniform way of interconnection between the vehicle and emergency call system should be investigated.

References

1. James P.Byrne. Association Between Emergency Medical Service Response Time and Motor Vehicle Crash Mortality in the United States.

2. URL: https://jamanetwork.com/journals/jamasurgery/fullarticle/2723267 (date of request 08.05.2020)

3. Harmonised eCall European Pilot: About eCall.

4. URL: http://www.heero-pilot.eu/view/en/ecall.html (date of request 08.05.2020)

5. Uconnect® Access. Emergency Assistance.

6. URL:https://www.driveuconnect.com/uconnectaccess.html (date of request 08.05.2020)

7. OnStar Services Help: Emergency Services.

8. URL: https://www.onstar.com/us/en/support/emergency-services/ (date of request 08.05.2020)

9. D2.2 - eCall systems functionalities' specification (2013).

10. URL:http://www.heeropilot.eu/ressource/static/files/heero2_wp2_del_d2_2_functional_specification_v1.0.pdf (date of request 08.05.2020)

11. FreeRTOS. What is An RTOS? URL: https://www.freertos.org/about-RTOS.html (date of request 08.05.2020)

12. CAN in Automation (CiA). CAN lower- and higher-layer protocols.

13. URL: https://www.can-cia.org/can-knowledge/ (date of request 08.05.2020)

14. Connectivity Technologies for IoT. Full Report. Northenstream.

15. URL:http://northstream.se/northstreamwp/wpcontent/uploads/2017/01/Northstream-White-Paper-Connectivity-Technologies-for-IoT.pdf (date of request 08.05.2020)

16. The 3rd Generation Partnership Project (3GPP). Standards for the IoT.

17. URL: https://www.3gpp.org/news-events/1805-iot_r14 (date of request 08.05.2020)

18. The 3rd Generation Partnership Project (3GPP). LTE.

19. URL: https://www.3gpp.org/technologies/keywords-acronyms/98-lte (date of request 08.05.2020)

20. Opensignal. The state of mobile network experience. Banchmarking mobile on the eve of the 5G revolution. May 2019.

21. URL: https://www.opensignal.com/reports/2019/05/global-state-of-the-mobile-network (date of request 08.05.2020)

22. GPS: The Global Positioning System. URL: https://www.gps.gov/ (date of request 08.05.2020)

23. Information and analysis center for positioning, navigation and timing. GLONASS history URL: https://www.glonass-iac.ru/en/guide/ (date of request 08.05.2020)

24. European Global Navigation Satellite System Agency. Galileo is the European global satellite-based navigation system.

25. URL: https://www.gsa.europa.eu/european-gnss/galileo/galileo-european-global-satellite-based-navigation-system (date of request 08.05.2020)

26. BeiDou Navigation Satellite System. White Paper. China's BeiDou Navigation Satellite System. URL: http://en.beidou.gov.cn/SYSTEMS/ WhitePaper/ (date of request 08.05.2020)

27. Quasi-Zenith Satellite System (QZSS). Overview of the Quasi-Zenith Satellite System (QZSS). URL: https://qzss.go.jp/en/overview/services/sv01_what.html (date of request 08.05.2020)

28. Department of Space, Indian Space Research Organisation. Indian Regional Navigation Satellite System (IRNSS): NavIC.

29. URL: https://www.isro.gov.in/irnss-programme (date of request 08.05.2020)

AUTHORS

Anna Bezverkhnia– student, Department of Computer Engineering, National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”.

E-mail: annabesverkhnia@gmail.com

Artem Volokyta (supervisor) – associate professor, Department of Computer Engineering, National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”. E-mail: artem.volokita@kpi.ua