

A Review on Current eCall Systems for Autonomous Car Accident Detection

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Abstract: The aim of the paper is to give an overview on the existing eCall solutions for autonomous car accident detection. The requirements and expectations for such systems, considering both technological possibilities, legal regulatory criteria and market demands are discussed. Sensors utilized in e-call systems (crash sensing, systems for positional and velocity data, and communication solutions) are overviewed in the paper. Furthermore, the existing solutions for eCall devices are compared based on their level of autonomy, technical implementation and provided services.

1. INTRODUCTION

Nowadays traffic accidents are still one of the leading causes of death through the whole world [1]. As it was proven by previous researches, the consequences of traffic accidents regarding the injuries of those affected is strongly depending on the response time of the emergency services: the time that takes place between the occurrence of the accident and the arrival

of services to the site, and also on the level of informed status of the emergency regarding the number and condition of the injured person [2].

Automated car accident detection, or eCall systems, can save lives or decrease the seriousness of injuries by relaying crucial information to emergency responders and thus reducing their response time significantly (by 50% in rural and 40% in urban areas [3]).

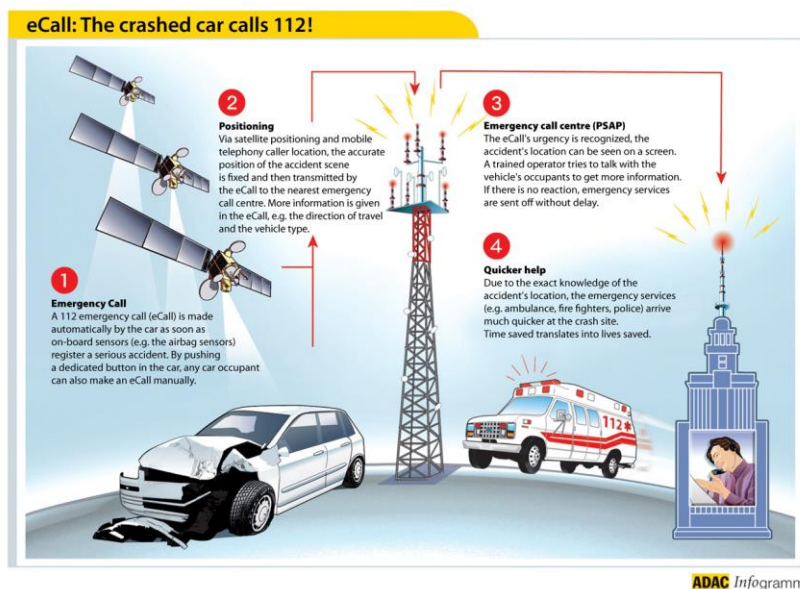


Fig. 1. The concept of eCall systems [4].

Due to these reasons, in 2015 the European Parliament voted in favor of a new regulation (eCall), which requires all new cars to be equipped with this technology from April 2018 [4]. With legal regulation is being established, the development of fully or semi-autonomous eCall systems/devices to be used with older cars is moving into the focus of automotive and tech companies, with several commercial products already on the market.

2. eCALL SYSTEMS IN GENERAL

eCall is an emergency call that can be generated either manually by vehicle passengers or automatically via activation of in-vehicle sensors when a serious road accident occurs. When activated, the in-vehicle eCall system establishes a 112-voice connection directly with the relevant Public Safety Answering Point (PSAP). Even if no passenger is able to speak, for instance due to injuries, a ‘Minimum Set of Data’ (MSD) is sent to the PSAP, which includes the exact location of the crash site, the triggering mode (automatic or manual), the vehicle identification number, a timestamp, as well as current and previous positions. This way, information, that is valuable for emergency responders, is reaching them as soon as possible [6].

The most common expectations from eCall systems are to autonomously detect accidents, to inform the emergency response services and convey information such as the location and maybe the number of affected individuals. While the eCall initiative requires the car/device to be directly connected to 112, a Europe-wide single emergency number (see the illustration in Fig.1), other systems, like may offer separate emergency networks or other additional support as well. These systems are referred to as ‘TPS eCall’ (TPS: Third Party Services), while the ‘112 eCall’ is often mentioned as ‘Pan-European eCall’. The main difference between the two approaches is that while the 112 eCall is directly connected to PSAPs and is aimed to be a public (free) service), TPS based eCall alerts first go to a third party, where they are usually evaluated before addressing the relevant PSAPs in turn (see Fig. 2). Thus, TPS eCall systems are usually paid services, and are regulated by different European Standards (EN16102) compared to the public 112 eCall (EN16062 - High Level Application Protocols, EN16072 - Operating Requirements) [6]. Another standard (EN15722) specifies the standard data concepts that comprise the "Minimum Set of Data"

(MSD) to be transferred from a vehicle to a PSAP in the event of a crash or emergency.

The contents of the MSD are the following [14]:

- Message identifier (MSD version);
- Activation: whether the eCall is manually or automatically activated;
- Call type: emergency or test call;
- Vehicle type: passenger vehicle or commercial vehicle, cars, buses, motorcycles etc.
- Vehicle identification number (VIH);
- Vehicle propulsion storage type (e.g. gasoline, diesel etc.)
- Time stamp;
- Vehicle location;
- Confidence in position;
- Direction.

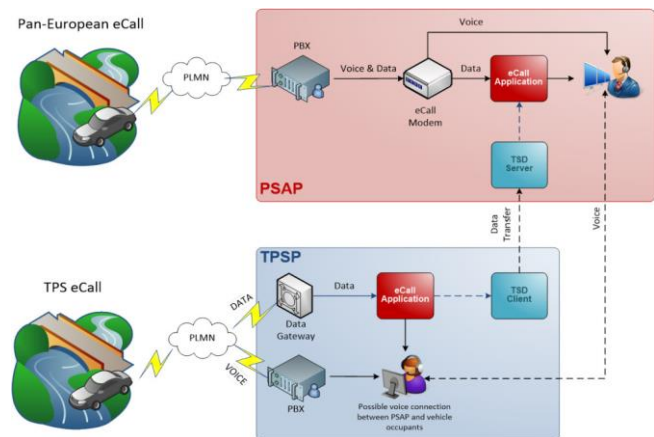


Fig. 2. Comparison of TPS eCall and 112 ‘Pan-European’ eCall systems [31].

Between 2011-2014 a European Commission co-funded project (HeERO - Harmonised eCall European pilot) was launched with a Bulgarian and a Turkish pilot test site (HeERO phase 1 in 2011-2013 & HeERO phase 2 in 2013-2014). 15 countries carried out the start-up process of an interoperable and harmonised emergency call system, and as a result of the project 14 Member States became aware and trained exactly how to deploy eCall already 4 years before the official and obligatory start of eCall in every new car [31].

The currently available eCall solutions fall into three main – but partially overlapping – categories based on the hardware they use for detection and communication. 1. The classic built-in solutions completely rely on the sensors, location and communication services of mostly newer vehicles. 2. The ‘black-box’ solution covers fully or semi-

autonomous, standalone or deployable devices, which have personal hardware for sensing, location and communication functions. 3. Finally, there are more and more applications and services which utilize the capabilities of smartphones to use them for eCall functions. Besides their hardware, available eCall systems significantly differ on their provided services. Our paper aims to give an extensive review regarding these solutions and to compare them based on their most important technical characteristics, functional capabilities and future prospects. Finally, we also give a short overview on Event Data Recorder (EDR) systems as well. Unlike to the on-line eCall systems, the purpose of EDR is passive, off-line data recording for subsequent event reconstruction. However, the presence of such systems in a large number of vehicles would justify the idea of their transformation/upgrade into on-line eCall systems, as a valid possibility.

3. BUILT-IN UNITS

The approaching deadline of the European eCall regulation urges the car industry to equip their newer models with built-in eCall systems. A superior advantage of such units is that through the on-board computer they can access the status of any sensor in the car. This means both a more precise way to determine the event of an accident (e.g. besides the acceleration, the status of the airbags can also be used), and also more information which could be relayed through the emergency call (e.g. number of the passengers is assessable e.g. from the status of safety belts). Another advantage compared to black-box units and mobile phones is that built-in systems are much harder to get severely damaged or ejected during a serious accident.

The Intelligent Emergency Call system of a German automotive company, for example [24], is automatically triggered by the deployment of airbags and calls the company's Call Centre via an accident-proof telephone unit permanently installed in the vehicle. Specially trained personnel will then establish contact with the passengers, inform the emergency services and give them support by telephone. To enable rescue services to promptly prepare the required care for those involved in the accident, a data transfer is performed which includes the precise position of the vehicle to the nearest meter in addition to other data relevant for the rescue services, such as risk of injury, number of passengers, model and color of the vehicle [24].

Most other European car manufacturer companies [25-30] have nearly the same solution in their models. The most common properties are, that they use the deployment of airbags for sensing and they call a private company call centre (TPS eCall system), though other details of their services may differ.

4. 'BLACK-BOX' SOLUTIONS

In the 'black-box' eCall section we cover fully or semi-autonomous, standalone or deployable devices, which have personal, dedicated hardware for sensing, location and communication functions. These are often called as 'Retrofit eCall' devices, which emphasize their main purpose to extend eCall to older car models without built-in units. The need for such devices is high, especially in Eastern European countries where the average age of vehicles is much higher compared to Western European countries. Besides the obvious needs, retrofit eCall devices could be a real risk for the whole TPSP model, since with low-cost and low quality retrofit devices the chances of PSAPs overloading with false direct 112 calls could be high [11]. Perhaps that is the main reason why only a few market-ready solutions could be found up to this point. However, several companies have their own solutions under development, which we will also summarize.

4.1. A Retrofit eCall module

The Retrofit eCall module (TEP-110) of a German company (Fig. 3) is designed to fit into SAE J563 12 V socket of cars. It detects car crash with a 3-axis acceleration sensor and intelligent embedded algorithm, which also determines the severity of the crash. The crash data (including GPS position and driving direction) is sent to an emergency center via an application, which is installed onto a smartphone, with which the module connects via Bluetooth. In case of a heavy accident the emergency call center organizes an ambulance. Extra services include guidance to the next repair shop, start claims process and more [10]. The module itself houses a microcontroller (ARM), an accelerometer and a Bluetooth module – showing a simple and effective concept for the specific application. A possible weakness of the solution is that the device relies on a smartphone for communication, which can easily be damaged in the case of a serious accident. Also, if the crash couples heavy forces into the cabin, the dongle type module may detach from the 12V socket. Also, the phone must be connected to the internet during the Bluetooth connection with the

module; and while the module houses an USB port, further sharing of this port (e.g. with a dual USB socket) is questionable from the aspect of power.



Fig. 3. The Retrofit eCall module [10].

For better reliability (but for a much higher price) the same company offers their Connectivity Control Unit (Fig. 4). This device is fully equipped with in-vehicle (I/O, CAN, Wi-Fi, PSI5) and external communication (mobile phone, router, internet) and location services (GPS, compass, GLONASS, Galileo, QZSS). Besides full eCall capability (in accordance with applicable law), it also offers bCall and iCall services. bCall provides help in the case of a breakdown, where the trained personnel of the contacted call center can help with either on-site repair (with remote diagnostics), or by sending a repair team to the location. With the use of iCall, the call center could provide information regarding for example the nearest location of petrol stations, restaurants, parking places etc. [23].



Fig. 4. The Connectivity Control Unit [23].

4.2. EuroGPS eCall

EuroGPS is a Bulgarian company, who is primarily involved in fleet management and GPS tracking and control systems. They are also an EU funded developer of an aftermarket eCall device and has worked closely

with the European Commission and ERTICO ITS-Europe on the development within the scope of the HeERO2 and the ongoing I-HeERO project [12]. Their system allows for emergency calls to be triggered either manually by vehicle occupants or automatically, as soon as vehicle sensors detect the impact of a serious collision. When activated, the eCall system establishes a voice and data connection with the relevant PSAP (either public or private).

Their device, SmartTracker IVS-EU014, which can be seen in Fig. 5, contains an inertial system with 3-axis acceleration sensor and 3-axis gyroscope sensor for automatic eCall triggering, and also a 32 channel low-power positioning system supporting GPS (L1), Glonass (L1, FDMA), and Galileo (E1) [13].



Fig. 5. The EuroGPS SmartTracker IVS-EU014 eCall System [13].

A highlight of their system is that their eCall environment was tested extensively with several thousand real life test calls and a PSAP in Sofia [12, 13], in the framework of the HeERO projects.

4.3. Reference designs for development

Many IC manufacturers and electronics producers provide reference designs for future eCall applications.

U-blox' presented their own solution with a complete system, for the then proposed 2015 European eCall launch. Their design incorporates their own modules, such as: SARA-G3 GSM module with in-band modem, a LISA-U2 GMS/UMTS module, an UBX-G8030 GPS/GNSS receiver and a MAX-7 GPS/GNSS receiver module. The components are all considered to have automotive classification. [15] Their IVS solution waits for trigger signals from the vehicle, and connects to an audio module (Fig. 6).

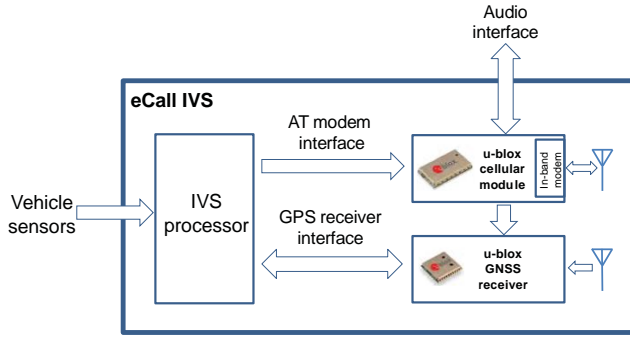


Fig. 6. IVS concept from u-blox [15].

Texas Instruments shared an open source design with their TIDA-00159 reference design board (Fig. 7) for automotive eCall. The board has a support of 3GPP LTE FDD and TDD, LTE-Advanced, 3GPP FDD/HSPA/HSPA+, GSM/EDGE/EDGE Evolution, TD-SCDMA, WLAN and several other standards. The reference board is designed with automotive components on mind [16].



Fig. 7. TIDA-00159 from TI [16].

The system does not contain the logic for emergency detection, however has a backup battery for emergency cases. It can be extended with a reference design for an audio subsystem [17]. This subsystem has onboard diagnostics for speaker status, and it is optimized from the aspect of reduced power and heat. It provides 8W output for loud sound in emergency cases. TI also supports developers with a reference design for an eCall Power Supply solution [18].

Infineon approaches the eCall topic from the aspect of automotive e-security. Their SIM controllers (SL 76 and SLI 97) are designed to support communication with hardware crypto-coprocessors for enhanced security in embedded SIM subsystems [19]. They also support communication module design with a suggested Application Processor (TC23x), and a CAN transceiver (TLE7250G) for receiving trigger signal for emergency detection (Fig. 8).

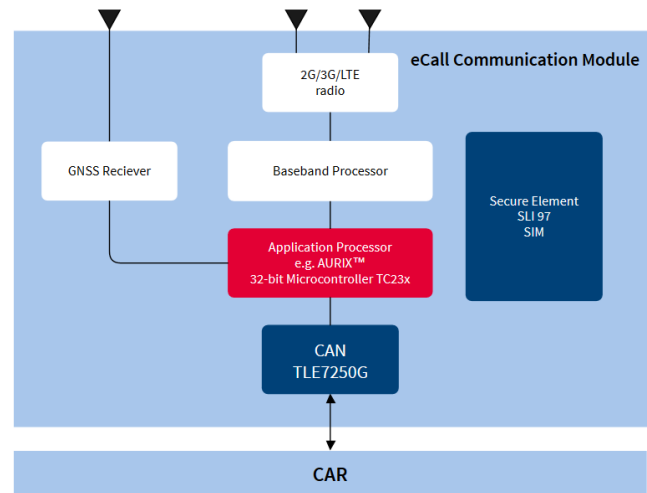


Fig. 8. Infineon reference design [19].

The reference design of Embitel houses a CAN transceiver, a backup battery, a GSM module and an SST230 microcontroller core. It may contact to an additional manual trigger, an antenna system, and a connection to audio modules (mic/speaker) [20].

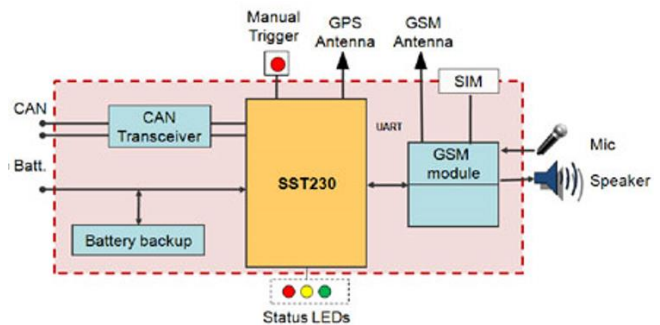


Fig. 9. Embitel reference design [20].

Targa presented a non-invasive OBD connector completely compatible with different telematics software. Via their Plexer module data can be read from the CAN bus. GV 300 module has implemented 3D accelerometer, voice communication support and GPS odometer. The module supports RFID reader, iButton and Temperature probe extensions [21]. Their solution tends more to the topic of fleet management, rather than public eCall services, however their device constructions incorporate valuable ideas for future eCall device constructions.

Qualcomm also presented their eCall specific (PSAP and IVS) modem solutions within 3GPP project [22].

5. MOBILE PHONE BASED SOLUTIONS

With the explosive spread of mobile communication devices (and later smartphones), today we can say, that nearly all of the passengers of a randomly selected car possess all the main technical components, which are required by an eCall system (sensors, location services and GSM communication) right in their pockets. The idea can justifiably arise to use mobile phones as “standalone” eCall devices, or accident detectors. The most valid argument against this is that presumably a mobile phone is even less reliable and prone to false alarms as a dedicated ‘black box’ solution (see Section 4). To counter this assumption, two out of four mobile crash detection applications use smart algorithms based on real accident sensor data to distinguish false positive triggers (e.g. phone drop). Also, the reliability of the method is strongly in question due to the fact, that mobile phones can be easily damaged in case of an accident (e.g. placed in a phone holder on top of the dashboard, or fixed to the windshield). Due to these reasons most of the existing mobile applications can only be used to notify pre-selected emergency contacts in case of an accident, except for the Crashdetect app, which (with subscription at the specific location) is connected to a South African TPS Network (see Table 1 for the comparison of the four systems).

Table 1. Comparison of the mobile phone based applications for car crash detection and contact notification.

| App name | Coverage | Medical Assistance | Smart algorithm |
|-------------|--------------|---------------------------|-----------------|
| Crashdetect | South Africa | Yes (with subscription) | Yes |
| SOSmart | General | Only contact notification | Yes |
| Car Crash | General | Only contact notification | No |
| Chrash App | General | Only contact notification | No |

5.1. Crashdetect

As an award winning mobile application, developed for the roads of South Africa, Crashdetect uses smart drive-detection technology to automatically monitor the trips of the user. It auto-detects serious car crashes and alerts the CrashDetect emergency contact centre of the location. The system immediately dispatches the nearest emergency medical services and supplies them with the medical information of the passengers [5].

Crashdetect has different subscription options which give various levels of services. Free license only contains the alert of pre-selected contacts, it does not include medical response. Live subscription gives access to the full Crash Alert service, which contacts the emergency centre in case of an accident. There, a medically trained agent calls the phone of the user to confirm that he/she needs assistance. If the user confirms or does not answer, the agent will immediately dispatch the nearest emergency medical services to the accident location and supply them with the medical information of the user. The most notable extra services accessible with advanced subscriptions are the following: Medical ID is a unique ID that is placed on the inside of the car’s window. Emergency medical responders scan the QR code or phone the Crashdetect emergency contact center in order to gain secure access to the medical and emergency contact information of the user. The Medical ID offers a fail-safe patient identification method, should a smartphone device be severely damaged during a car crash. Family Protect allows up to 5 family members to install and use CrashDetect on their phones. RoadCover is a service that manages the user’s claim with the Road Accident Fund from start to finish [5].

5.2. SOSmart

SOSmart detects car accidents using the internal sensors (accelerometer and GPS) of the smartphone, and sends an emergency notification with the user’s location to the pre-selected emergency contacts. This allows the contacts to send help as soon as possible. However, the application is currently not directly connected to emergency services. SOSmart car accident service can be configured in manual mode or automatic mode. Automatic mode: whenever SOSmart detects the user is in a moving vehicle, it will automatically turn on the crash detection monitoring. Manual mode: the user must manually turn the monitoring system in the app. The crash detection algorithms provided by SOSmart is based on real car crash data from the National Highway Traffic Safety Administration (USA). Using this data the algorithm can differentiate when the user drops the phone, brakes too hard or had a minor accident avoiding false alarms [7].

5.3. Car Crash

The Car Crash application uses GPS and accelerometer sensor to detect major slowdowns that could be caused by a traffic accident. In case of an

accident the smartphone will be sent a notification to the device of the user, which in the case of not being canceled at the predetermined time it will send an SMS to a relative or friend who has been previously selected. The SMS will contain important information such as the direction of the accident [8].

5.4. Crash App

As a rather simple accident alerting application, Crashapp allows the user to select a Crashapp buddy to watch over him whilst he goes on your journey - be it hiking, biking, skiing, horse riding or driving. The user can remain safe in the knowledge that the Crashapp buddy is keeping an eye in the background. They will be alerted of the user's exact GPS location if he/she comes into any danger [9].

6. EVENT DATA RECORDER (EDR) SYSTEMS

Since September 2014 a so called Event Data Recorder (EDR) is mandatory for every new passenger car and new light commercial vehicle (LCV) in the US. The purpose of EDR is to collect data about the vehicle dynamics and the vehicle status that enable better accident reconstruction. It helps in validating insurance claims, encourages safer driving behavior and extends the scientific knowledge about the real accidents, thus resulting in safer vehicle design.

The recorded data is stored in a dedicated memory part of the Airbag Control Module (ACM). There is a time window around the crash event (5 seconds before the event and 2 seconds after the event) that is sampled at 200 Hz frequency with the relevant data. There is a minimum set of data that must be stored in any case and there are options to store additional information as well. According to the American Act (49 CFR Part 563), the minimum set of data are:

- Delta-V, 0-250ms, every 10 ms;
- Maximal Delta-V, 0-300 ms;
- Maximal Delta-V in timeline, 0-300 ms;
- Vehicle speed, 5 seconds, 2 values for a second;
- Engine speed, 5 seconds, 2 values for a second;
- Braking ON/OFF, 5 seconds, 2 values for a second;
- Ignition cycle in the time of the crash;
- Ignition cycle, the data download time;
- Condition of seat belts – driver (fastened seat belt, unfastened seat belt);
- Airbag condition indicator (on/off);
- Activation of the airbag module, time until activation (driver, passenger);

- More values in the EDR memory, number of event (numbering of EDR storage events);
- Time between Event 1 and Event 2;
- Status of EDR data downloading (downloaded complete without errors – yes/no).

From a point of view one can say, that the eCall system is the European answer for the EDR. The major difference between the two systems is that the EDR is an offline system, requiring a later data retrieval from the EDR device, while eCall is an online system that immediately calls the ambulance (dials 112) in case of emergency. Though EDR is not mandatory in Europe, due to the side effect of the US regulation an approximately 4-6% of the EU vehicles are equipped with an EDR device.

The importance of an EDR like a “black box” increases with the deployment of highly automated functions into the road vehicles, since there has to be an objective evidence for who was in charge of control in the vehicle in the critical situation. It is also obvious that the minimum set of data must be extended in case of automated or highly automated vehicles (level 3 and above). Accident researchers and automated vehicle experts are working together on the new regulations in this field.

Recent threats in attacking road vehicles through cyber security vulnerabilities showed that vehicle cyber security protection and prevention of misuse of the highly automated vehicles will be a key element of the future. As there are similarities in the forensic analyses methodology of accident reconstruction and cyber security event reconstruction, it might be useful to compare the data capture requirements from each side and evaluate EDR applicability for cyber security research purposes.

7. CONCLUSIONS

With the approaching deadline of the EU regulation, TPS eCall systems are already spread among the newer models of all major European car companies. These systems fully comply with EU standards and offer the highest possible level of reliability. Retrofitting older car models with portable “black box” eCall devices promises a large market, although up to this point only a few market-ready products exist, besides several reference designs for development. A couple mobile applications also offer a cheap, but much less reliable solution.

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