Next Generation Automated Emergency Calls

Specifying next generation eCall & sensor-enabled emergency services

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***Abstract*—*The Internet of Things (IoT) potentials to transform our modern society into smart environments that facilitate living and boost all types of transactions are becoming more and more evident as the number of interconnections between the physical and the virtual world keeps increasing. Cyber-physical systems, wide end-to end connectivity and handling of big data are some of the mainstream concepts brought forth to materialise the IoT umbrella. Yet, emergency services, a domain of paramount importance to society, reveal multiple challenges for the adoption of applications that capitalise on the capabilities of smart devices and the interoperability among heterogeneous platforms. In this paper, we present the continuing work [4] on next generation automated (non-human initiated) emergency calls by specifying the pathway to implementation of NG eCall and sensor-enabled emergency services.*

Keywords—Internet of Things; smart devices; telematic; sensor-based event detection; next generation emergency services; monitoring application; next generation eCall; sensor data.

I. Introduction

Billions of connected smart objects, embedded systems, and smart sensors have penetrated our world and changed our lives, under the IoT umbrella, connecting citizens, infrastructure and businesses [1]. Consequently, the future of IoT cannot be based on a single protocol, standard or technology, but instead it will require an ecosystem providing home to many actors participating in the service value chain. Regardless of the underlying service, enabling such an ecosystem mandates for an interoperable architecture capable to facilitate integration and collaboration of heterogeneous components, be these platforms, smart devices or applications. In the context of emergency services, the developments towards the wide proliferation and broad adoption of sensors, telematics technologies and the IoT preclude a future highly automated and environmental-aware, namely in what respects to the automatic detection and to the enhanced situational awareness of emergency incidents that have the potential to be critical elements for fast and effective emergency response, in the protection of citizens and the safeguard of lives. Hence, it is expected that Next Generation Emergency Services (NGES) will support automated emergency calls initiated by smart devices that may rely on sensors installed in vehicles (e.g., eCall systems) or in residences and facility buildings (e.g., seismic sensors, gas sensors and fire sensors) and in wearable health devices (e.g., heart rate monitor, fall detection). Aside from being capable of automatically initiating an emergency call and supporting voice and video when in the presence of the victim, smart devices will exhibit the ability to provide relevant data about the caller and the event to be interpreted by Public Safety Answering Point (PSAP) operators. Automated sensor and data-enabled emergency calls are two examples of the major changes in paradigm in the traditional way of handling emergency calls worldwide. In this work, we present specifications in terms of architecture, flow of actions and data structure for two applications of automated emergency calling: i) the next generation eCall (NG eCall) and ii) a sensor-based monitoring system, involving eHealth devices or smart environmental sensors, that is capable to automatically detect emergencies and place emergency calls.

This work has been prepared as part of the NEXES Research and Innovation Action, which has received funding from the EU's Horizon 2020 research and innovation programme under Grant Agreement No. 653337.

II. Related Work

eCall is a European initiative aiming to implement a in-vehicle caller device built upon the single European emergency number (112) that, in case of a serious accident, automatically creates a voice link to the closest 112 PSAP. It was originally developed considering emergency calls originated from circuit-switched (analogue) mobile telecommunications infrastructures, specifically 2G and 3G networks using an in-band modem. As technologies evolve and NGES adopt a 4G communications framework - fully digital IP-based [2] - the current eCall concept needs to be refined and adapted, so as to benefit from the resource-efficient packet-based systems. It is envisaged that the NG eCall concept refines the traditional one by using Session Initiation Protocol (SIP) and Minimum Set of Data (MSD) extensions. In addition, recent advances in smartphone technologies are making it possible to detect car accidents in a more portable and cost effective manner than conventional in-vehicle solutions. The pervasiveness of smartphones also means that the infrastructure required to establish the wireless mobile sensor network is already in place and available, after installing appropriate application software. Smartphone manufacturers also have begun including a plethora of sensors that enable devices to detect the context in which they are being used. For example, an Android-based device with a compass, accelerometer, and GPS receiver allows application developers to determine the user's geographic position, orientation, and motion. The processing power, popularity, and relatively low cost [3] make smartphones an appealing platform to construct a wireless mobile sensor network that detects car accidents. Moreover, embedded systems and sensors, either mobile or stationary, have been traditionally used to monitor status and behaviour of objects of any kind. Going a step further, utilising the data they generate makes it possible to enable automated reactions when a specific event is detected. In other words, the automated emergency calling is thus possible where the sensor data initiate the emergency calling process in the same manner a human would. It is of the outmost importance though to embed in the sensor and data enabled emergency calling the functional elements that allow incident and event creation, event identification, alerting and distribution as well as the data consuming process. For example, a smart building equipped with fire and smoke sensors, may act on its own when a fire bursts and inform via a dedicated emergency call streaming the data showcasing the anomaly to the PSAP operators and related emergency actors which become rapidly aware of the magnitude of the event. Moreover, the sensor enabled system allows to remotely initiate a more coordinated and situational-aware response, including the possibility to turn on auxiliary monitoring tools (additional sensors), such as cameras, loudspeakers and microphones.

The previous examples showcase that NGES bring enhanced communication and end-to-end connectivity between citizens and emergency services, using Total Conversation (TC) calls (combination of text, audio and video), and providing emergency services with more and richer data, such as device location, telematics and sensor data, which contribute to improve the level of situational awareness and emergency response. It is thus evident that the NGES concept "glues" vertically oriented (and closed) IoT systems from the transport, health, infrastructure and civil protection domains and subsequently enhances (transforms) them into smart environments with dynamic and adaptive configuration capabilities that are seamlessly communicating as an interoperable ecosystem supporting a quicker and more effectively coordinated response to emergency situations.

III. PROPOSED ARCHITECTURE

Continuing the work of [4] and advancing from use cases and conceptual description, we provide herein the architectural frame, the respective data structures and the state flows that will permit realisation of automated calls in the context of next generation emergency services. Even though the NG eCall and sensor enabled automated NGES use cases are tackled separately in this paper, the proposed architectural, data and transactions frameworks facilitate interoperability of disparate IoT platforms and heterogeneous IoT systems towards exchanging resources (both with end-users as well as among themselves). For both use cases, the *Gateway* component supporting backward compatibility with well-established working IoT solutions [19], implements device and network management layers as well as service and application support. This component is considered a *mobile Gateway* unit as the architectural framework can be functionally enabled in portable devices such as smartphones and micro processing units [20]. Moreover, the *Gateway* component allows end-users to discover the appropriate IoT resources (connected devices, enabling services and data) though ontology-based modelling and will enable bidirectional communication for things connected through different local and wide network protocols, such as ZigBee, Bluetooth, WLAN and cellular next generation networks. Given the implicit IoT registration process, the *Gateway* component also features wisdom extraction which is basically the embedded logic depicted under the transactions framework to automatically exchange resources (notifications, sensor and device data, switch on/off and reconfigure smart objects, etc.).

A. NG eCall architecture

Transitioning to next generation emergency calling for eCall, provides an opportunity to vastly improve the scope, breadth, reliability and usefulness of data relative to an accident by allowing it to be transmitted during call set-up, and to be automatically processed by the PSAP and made available to the call taker in an integrated and automated way. Additionally, a PSAP call taker may request a vehicle to take certain actions, such as flashing lights or unlocking doors. Furthermore, vehicle manufacturers are provided an opportunity to take advantage of the same standardized mechanisms for data transmission and request processing (such as telemetry between the vehicle and a service centre for both emergency and non-emergency uses)). Based on the NG Pan-European eCall specification [2], we identified the relevant high-level requirements to be satisfied by the eCall and the NG eCall systems, as presented in Table 1.

eCall	NG eCall Added Features
The call is recognised as an eCall (inherently an emergency call)	The call is able to carry more data (e.g., an enhanced Minimum Set of Data or an MSD plus additional sets of data)
The call setup indicates if the call is manually or automatically triggered	The call is able to handle video
The call is able to provide a voice channel between the vehicle and the PSAP	The call is able to handle text
Carries the MSD intrinsically with the call (the MSD needs to be available to the PSAP operator as the voice call)	The PSAP is able to access vehicle components (e.g., on-board cameras used for parking for a visual assessment of the crash site situation)
The PSAP is able to acknowledge receipt of the MSD	The PSAP is able to request the vehicle to take actions (e.g., sound the horn, disable the ignition, lock/unlock doors)
The PSAP is able to request that the vehicle generates and transmits a new MSD	The call is able to simultaneously handle voice and data exchange
The PSAP is able to call back the occupants of vehicle after the initial eCall is terminated	
Supports a test call (which can be routed to a PSAP but is not treated as an emergency call and not handled by a PSAP operator)	

Table 1-Main Functional Requirements of Current and Next Generation eCall

The high-level architecture of the NG eCall service is based on the legacy eCall system [5, 6] and the need to consider modern user equipment (UE), such as smartphones. Applicable components thus comprise the client system and the eCall module in the PSAP system.

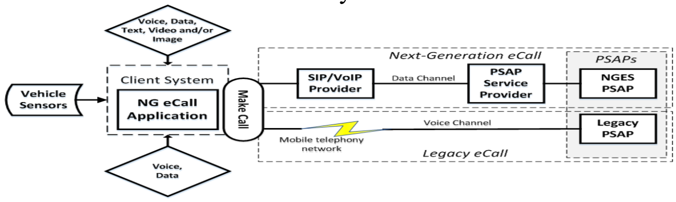

Figure 1-Architecture of the NG eCall

As depicted in Figure 1, and following the work developed in the European HeERO research project [7], the **NG eCall client system** combines two main modules: the **Vehicle Gateway**, responsible for gathering the relevant vehicle data (originated by the vehicle's internal and external sensors), and the **Client Device**, responsible to trigger, manage and effect the eCall transaction, including preparing and sending the MSD. The **Vehicle Gateway** is responsible for collecting the vehicle's internal (e.g. speedometer) and external (e.g. accelerometer device) sensor data and is able to indicate a *crash* condition based on these data values. It is usually a small vehicle industrial personal computer that interfaces with the vehicle's sensors. The **Client Device** may be a in-vehicle system (IVS) or a smartphone supporting IP connectivity and it is the component responsible for placing the NG eCall. Operation is assumed to be limited within a SIP-based environment, as per specifications in 3GPP's Technical Specifications TR 26.967 V8.0.1 [8]. The Client Device receives inputs (e.g., vehicle sensor data) from the Vehicle Gateway and hosts the NG eCall Application, i.e., a software that determines whether an eCall should be automatically initiated. The location is provided either by the Vehicle Gateway or directly by the Client Device (i.e., a GNSS-equipped IVS or smartphone or a location acquired from the smartphone's mobile network).

Residing in the user's smartphone or in the IVS equipment, the NG eCall Application is thus responsible to process the sensor (collected vehicle data, including a crash indication) and user (selection of voice, text or video) inputs, presenting user interface routines that should at least include a simple visual/audio interface where (i) the user may initiate an eCall (selecting NGES functions such as audio, video and real-time text) and (ii) the system may interact with the user to inform that an automated eCall was initiated. The NG eCall Application then uses a data communication channel, enabling TC and the eCall data exchange, to provide emergency call-related data to the PSAP centre, during an emergency call in an all IP environment. As per the Pan-European Mobile Emergency Application (PEMEA) recommendation, the data channel is offered by a SIP/VoIP provider (on the client side) and a PSAP Service Provider (on the PSAP side) [9]. For purposes of interoperability with legacy PSAP systems, a voice-only channel is also included to support communications [9, 2].

Considering the NG eCall activation, we consider both manual and automated activation modes, following the IETF recommendation [10]. Figure 1 furthermore includes the **NG eCall module in the PSAP system**, an example of the many adaptations and upgrades existing PSAP systems will be undergoing to capture the opportunity brought by IoT, automation and the new IP-enabled technologies and integrate more and new types of data in the information exchange between citizens and PSAPs in emergency situations.

B. *Sensor-based automated emergency call architecture*

It is ambitioned that NGES systems incorporate smart devices, such as sensors, smartphones and tablets, and explore their applicability to initiate emergency calls, either automatically or upon user initiative, and transfer relevant data to emergency services to improve emergency response efforts. Sensor data envisaged as relevant in emergencies and ambitioned to be included in the NG emergency information loop includes data from environmental sensors (e.g. temperature sensors, accelerometers) installed in specific building locations. Smart buildings are bound to contribute to the creation of monitored grids across smart cities and their role in the emergency context is significant since monitoring will effectively sense critical environmental conditions, namely fire spreading, gas leaks or earthquakes. Other data deemed important in emergencies are the data from health sensors, i.e. from wearable devices on citizens with known medical conditions or citizens experiencing disability or special needs, as well as the data from integrated sensors embedded in smartphones and tablets, such as accelerometers or gyroscopes.

In the context of health sensors and devices, smartphones or tablets would act as intermediate gateways to collect the sensors data through a smartphone application and send it via wireless links, utilising available technologies, such as 4G or Wi-Fi, to a web server application.

Two sensor-based NGES applications in a similar manner as described in [4] will be investigated and explored: a smart building application and a smart health application.

Depicted in Figure 2, the **smart building application** delivers a monitoring capability over the building floors based on the data provided by a combination of sensors comprising smoke detectors, accelerometers, thermometers and gas sensors.

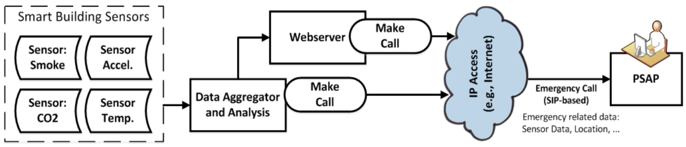

Figure 2-Smart Building Application

Sensor data is aggregated by a *Data Aggregator and Analysis* component and it may be applied to indicate an emergency situation. If deemed appropriate, this component may initiate an automated emergency call. In alternative, the automated emergency call may be established by the *Webserver* component, deployed to collect the relevant data from the *Data Aggregator and Analysis* component. This alternative may be particularly useful in case the *Data Aggregator and Analysis* component does not have the capability – or is not intended – to initiate emergency calls or in situations where a third party is responsible for detecting anomalies and initiating (manually or automatically) emergency calls. In this setting, location information details are predefined in each sensor (assumed fixed), allowing the PSAP operator to accurately determine exactly where (i.e., address, floor and room) the incident is located.

The **smart health application**, illustrated in Figure 3, acts as a personal health monitoring application, recording the user's health parameters by means of sensors connected to the user's smartphone. In addition, smartphone sensors, such as the accelerometer capable to detect falls, are also considered when collecting the user's health data. A NG emergency App, residing in the user's smartphone, analyses the collected sensor data and may initiate an automated emergency call if abnormal or life-threatening indicators are detected.

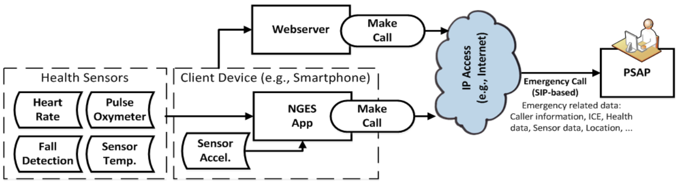

Figure 3-Smart Health Application

Similarly to the smart building application, in the smart health application a *Webserver* component can be deployed to collect relevant data from the user's smartphone (or multiple users' smartphones) and be used instead to initiate an automated emergency call, which may be particularly useful in case a third party is involved in the detection of anomalies and the (manual or automated) initialisation of the emergency call. Location information is also collected using the smartphone's capabilities.

It should be noted that, because personal health monitoring does involve human presence, the PSAP operators would expect some sort of human interaction when receiving an emergency call. On the contrary, the smart building application may encapsulate a fully automated environment without human involvement. Despite the different operational procedures, the PSAP's call-back capability should be supported by NGES smart devices applications: after receiving an automated emergency call, the PSAP operator would be given access to the transferred emergency-related data (e.g., query the web server component and collect relevant details), in order to improve the situational awareness and act accordingly.

IV. Proposed Data structures

Whether an automated emergency call is established by a NG eCall service, a smart building application or a smartphone's sensors or personal health monitoring application, the additional data it generates with respect to the emergency and transmits to the PSAP operator is bound to have a significant impact in the emergency services' situational awareness and dramatically improve the efficiency, effectiveness and outcome of the emergency response effort.

Based on the work conducted by several institutions and standardisation bodies, including 3GPP, CEN, EENA, IETF, ETSI and NENA [11], we have selected and combined the elements of information required for a reference implementation of a NGES. A summary of the structures to be contained in an extended emergency call dataset as well as the relevant sources is presented in Table 2. With regards to the data transmission in the NG Emergency Calls, the following apply:

- The mechanisms described in [2] allow the additional data to be conveyed by value (within the body of a SIP message or a location object) or by reference (as an external resource). This feature follows the tradition of prior emergency services standardisation work, where data was conveyed by value within the call signaling (i.e., in the body of the SIP message) or by reference.
- The IETF's *Additional Data related to an Emergency Call* document [10] establishes a general mechanism for attaching blocks of data to a SIP emergency call. However the size and frequency of additional data transmission during a session needs to be evaluated to ensure its appropriateness to use the signaling channel in detriment of the inclusion by reference.
- The vehicles designed for multiple regions might need to support NG eCall and other Advanced Automatic Crash Notification (AACN) systems, such as described in [15].

Data Category	Description	Reference
Data Provider	This block supplies name and contact information for the entity that created the data	[10], page 9
Service Information	This block supplies information about the service	[10], page 17
Device Information	This block supplies information about the device placing the call	[10], page 22
Owner/ Subscriber	This block supplies information about the owner of the device or about the subscriber	[10], page 27
Short Message	This block provides a way to supply free form human readable text to PSAPs or emergency responders	[10], page 31
General Data	This block supplies general information, such as message id and current location	[12, 13, 14]
Vehicle Data	This block supplies information regarding the vehicle from which the call was originated in case of automotive applications Note1: Contains parts of crash related data as defined in VEDS [16]. Note2: Requirements for eCall provided in Next-Generation Pan-European eCall draft-ietf-ecrit-ecall-07 [2] The investigation for vehicle related data suitable for emergency response was guided by [2].	[11, 14, 15]
Health Data	This block supplies medical profile data regarding the owner of the device or the subscriber. Note: Contains parts of medical profile data as defined in VEDS [16]	[16]
Sensor Data	This block supplies sensor data resulting from the detection of an emergency event by an eCall or a smart device. Events can consist of e.g., heart rate high variability, fall detection, crash detection, smoke detection and CO^2 level overstepping detection.	NEXES [17]
Additional Data	This block can be used to transmit additional data (such as specific sensor data in case of automotive applications) or undefined data	[16], page 16

Table 2-Data Categories to Support Automated NG Emergency Calls

V. Implementation of communication transactions

The capabilities to be introduced through the NGES architecture through the integration of gateway(s) and message broker(s) permitting on demand and automated bi-directional communication include (1) to generate and receive alerts, (2) to support TC, (3) to configure the smart devices and (4) to exploit centrally rich sets of data streams that contain text, audio, images and video.

To do so, it is important to establish the proper flow of actions that govern such information exchange as per below cases:

NG eCall – PSAP communication flow

Figure 4 provides the NG eCall state flow adopted (after modifying the legacy eCall specifications and the traditional communication flow between the car and the PSAP to NG environments [18]), based on the traffic collision use case presented in [4]. The states are used for sequential design to create state transition sequences, the processes are represented with boxes and the control blocks are denoted with rhombus. It is worth noting that steps 1 and 2 of the traditional eCall process [2] are now considered obsolete, as well as step 7, included in the *Successful Communication* control block. The term *Dataset* represents NG eCall extended set of data, comprising both vehicle data and user data, as defined in [10].

It is assumed that once the NG eCall is triggered, the NG eCall Dataset is transferred and, sequentially, communication with the user is attempted. Although this process is not mandated by SIP, it is deemed more efficient to have the PSAP operator receiving the user data before the communication is actually initiated. The communication means used (voice, video or RTT) abide to the user's preference/profile, although it is possible for the user or the PSAP operator to request an alternative communication channel after the communication has been initiated. Once a successful communication has been established, the PSAP operator may request for:

- Dataset retransmission - The PSAP may request for dataset retransmission whenever it considers appropriate during the duration of the call (the same is specified for the legacy eCall [18]). Note that in [15], the opposite scenario is proposed to be supported too: "If the IVS is aware that previously sent VEDS[1] data has changed, it may send an unsolicited VEDS during the call».
- Remote control of vehicle subsystem (optional – indicated with dashed lines in Figure 4) - Following the draft standard [15], the PSAP may optionally[2] request access to control a vehicle subsystem that is considered relevant for the emergency response such as turning on the flashers or the lights, remotely unlock doors, honking the horn or enabling an exterior/interior vehicle camera.

In order to enable such options, the possible actions and data types relevant to vehicle indicators and subsystems (such as available lamps and cameras) that are supported by the vehicle should be included in the emergency dataset transmitted by the IVS.

When communication fails, the following conditions are checked sequentially: the PSAP operator attempts to call back (voice call); if unsuccessful, the PSAP operator assumes the user is unable to speak or hear the call and requests that a text communication is established. If the request for a text communication is rejected, the PSAP operator assumes the user is unable to read or write and requests that a video communication is established. Video communication can only take place upon the prior consent of the user or/and the appropriate configuration of the vehicle, in case of a built-in camera system.

[1] The Vehicular Emergency Data Set (VEDS) is a XML-based data standard that determines useful & critical elements needed for an efficient emergency response to vehicular emergency incidents. The Protocol identifies crash and medical data elements. The full VEDS data definition can be found in [16].

[2] Remote control concept described inhere assumes the regulatory framework in existence permits the requested actions to be performed from the PSAP side. The concept is presented as optional (dashed lines in the diagram) since this is not the current situation where vehicle internal communication network as well as vehicle subsystems' use is proprietary by car manufacturers.

Procedures are also required for cases where other failures occur, including the incorrect transmission of the dataset, the dataset not being sent, the dataset not being received, the false generation of eCall, the failure of network registration, the NG eCall routing to a non-eCall-capable PSAP or the failure of the PSAP system.

NGES Smart Devices – PSAP communication flow

In Figure 5, a NGES smart devices state flow presents the establishment of an automated emergency call.

A *Gateway* component is introduced to represent a generic device-agnostic responsible of initiating a NG emergency call. The *Gateway* component can be the *Data Aggregator and Analysis*, the *Smartphone* or the *Web Server* components described earlier. The applications' operation is assumed to be limited to a SIP-based environment and the applicable signalling mechanisms (e.g. message encapsulation inside SIP, call back mechanisms) are outside the scope of the state flow.

The state flow displays the presentation of several conditions to ensure a successful communication is established: the PSAP operator may request for Dataset retransmission, the PSAP operator may request for activation of auxiliary devices and the PSAP operator may access and modify data transmission configuration (e.g. increase data sampling). Moreover, specific procedures should also be defined for failure situations, namely the incorrect transmission of the Dataset, the false generation of automated smart devices emergency calls, the failure to register the network, among others.

VI. Conclusions and Future Work

The capability to empower the early detection of emergencies, including in situations where human intervention might not be possible or is impaired, as well as enhanced emergency situational awareness, benefitting from the real-time exchange of relevant information, are all the more reasons to adequately explore, implement and validate the embrace of automated NG emergency calls worldwide. Simply put, the adoption of the IoT paradigm by NG emergency services has the potential to revolutionise the quality of emergency response and save lives in the process.

The current work explores the integration of telematics and smart devices in emergency services, leveraging on three key enablers: total conversation, device data and location-aware devices. NG eCall, eHealth applications and smart environmental sensors constitute the platforms to concept-prove and showcase the added-value generated by automated NG emergency calls for a cost-effective, efficient and high-performing emergency response. Relevant information sources and data structure elements have been thorough analysed and the latter adapted to handle additional sensor data and define a framework for automated NG emergency calls that convey true innovation on new additional data structures capable of addressing the specificities of automated and data-enabled emergency calls.

The results presented in this paper constitute the needed baseline towards advancing in the implementation of the next generation emergency services applications that embed automation, convergence of disparate IoT platforms and sensor-based situational awareness.

ACKNOWLEDGMENT

The authors would like to thank all NEXES partners involved in the project for their valuable feedback and contribution on the context of the NGES.

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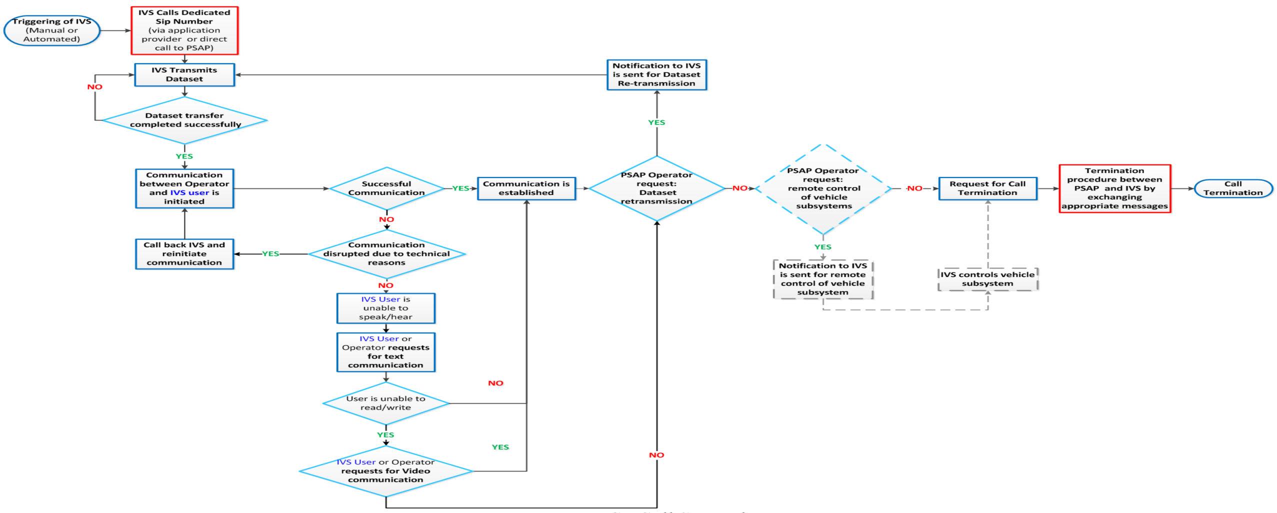

Figure 4-NG eCall State Flow

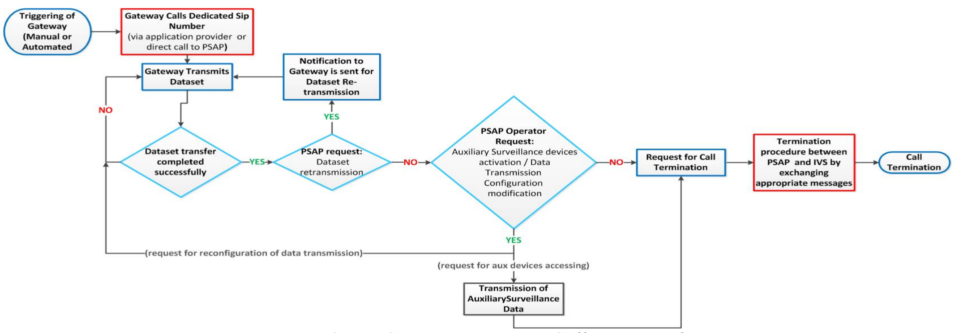

Figure 5-Smart Sensor Emergency Call Process Flow