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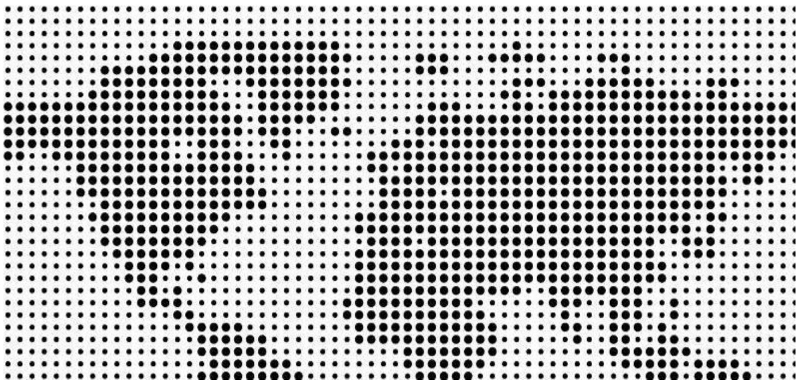

eCall Whitepaper
Version 1.5

QUALCOMM, Incorporated.
March 2009

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[1] Introduction

eCall refers to an interoperable in-vehicle emergency call service which is envisioned to be introduced and operated across Europe in 2010. The European Commission has brought together standardization bodies, the automotive industry, mobile telecommunication industry, public emergency authorities and others in the eSafety Forum initiative[1] which has identified high-level requirements, recommendations and guidelines for this eCall service[2].

The introduction and use of in-vehicle eCall for deployment of emergency assistance is expected to save many lives and reduce social burden by improving the notification of road accidents and speeding up emergency service response[3].

In the event of a collision, the intended solution can automatically or manually establish an emergency voice call (E112) via the cellular network to the local emergency agencies, i.e., the Public-Safety Answering Point (PSAP), as illustrated in Figure 1. Aside from enabling two-way speech communication between the motorist and the PSAP operator, eCall also allows transfer of a data message from the In-Vehicle System (IVS) over the cellular network to the PSAP which is denoted as eCall Minimum Set of Data (MSD). The MSD includes vehicle location information, time stamp, number of passengers, Vehicle Identification Number (VIN), and other relevant information.

As part of the eSafety initiative, ETSI MSG and the 3rd Generation Partnership Project (3GPP) were requested to standardize the eCall service.

For eCall data transfer, an in-band modem solution has been identified as the most suitable technology that fulfills all eCall requirements[4]. With this solution the MSD is transmitted "in-band" over the voice channel. This supports quick deployment of an end-to-end eCall solution in both vehicles and PSAPs.

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[1] *eSafety Forum: http://www.esafetysupport.org/en/esafety_activities/esafety_forum*
[2] *eSafety Forum eCall Driving Group, "European Memorandum of Understanding for Realisation of Interoperable In-Vehicle eCall", May 2004*
[3] *eSafety Forum, "Clarification Paper – EG.2 , High level requirements for a eCall in-vehicle system, Supplier perspective", March 2006, Version 1.0*
[4] *3GPP TR 26.967 V8.0.1 "eCall Data Transfer; In-band modem solution"*

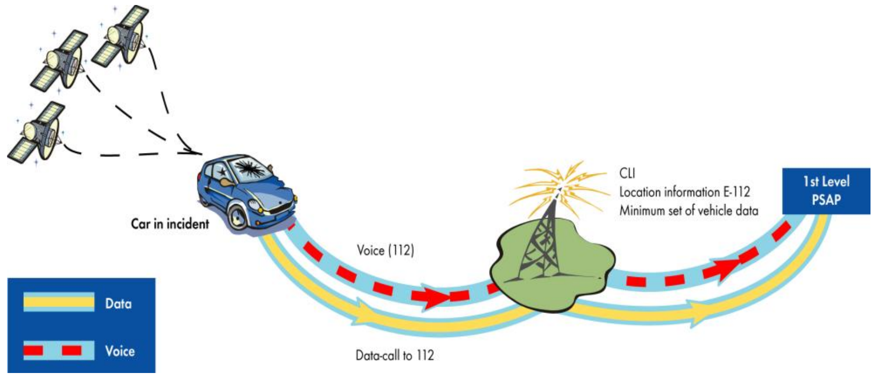

Figure 1. eCall system overview [5]

[2] Terms

ARQ – Automatic Repeat-reQuest. An error control mechanism for data transmission where the receiver requests retransmission of data that has not been correctly received.

BTS – Base Transceiver Station

IVS – The in-vehicle system which includes the eCall data modem, collision detectors, position location (e.g. GPS) function.

IVS data modem – The eCall data modem located in the IVS used to transmit the MSD information to the PSAP and receive feedback from the PSAP.

PLMN – Public Land Mobile Network

MSD – Minimum Set of Data to be sent from the IVS to the PSAP. This includes the location information of the vehicle, direction of travel, number of passengers with fastened seat belts, vehicle information, and other information deemed relevant for the emergency service agencies.

PSAP – Public-Safety Answering Point.

PSAP data modem – The eCall data modem located in the PSAP used to receive MSD information from the IVS data transmitter and transmit feedback to the IVS.

[5] *eSafety Forum, "Recommendations of the DG eCall for the introduction of the pan-European eCall ", April 2006, Version 2.0*

PSTN/GSTN – Public Switched Telephone Network/General Switched Telephone Network

TRAU – Transcoder and Rate Adaptation Unit

[3] References

1 eSafety Forum: http://www.esafetysupport.org/en/esafety_activities/esafety_forum
2 eSafety Forum eCall Driving Group, "European Memorandum of Understanding for Realisation of Interoperable In-Vehicle eCall", May 2004
3 eSafety Forum, "Clarification Paper – EG.2 , High level requirements for a eCall in-vehicle system, Supplier perspective", March 2006, Version 1.0
4 eSafety Forum, "Recommendations of the DG eCall for the introduction of the pan-European eCall ", April 2006, Version 2.0
5 3GPP TS 22.101 V9.0.0 "Service aspects; Service principles"
6 3GPP TR 26.967 V8.0.1 "eCall Data Transfer; In-band modem solution"
7 3GPP Tdoc SP-080474 "eCall Host Laboratory Test report (of the SelectionTest results obtained by each in-band modem candidate)"
8 3GPP Tdoc SP-080467 "TSG-SA WG4 (SA4) Status Report at TSG-SA#41"
9 "Additional Testing for the Selection of an In-band Modem Software for Transmission of eCall Data During Emergency Calls," from AT4 Wireless s attachment to [8].
10 3GPP TS 26.226 V8.0.0 "Cellular text telephone modem; General description"
11 3GPP TS 26.230 V7.1.0 "Cellular text telephone modem; Transmitter bit exact C-code"
12 3GPP TS 26.267 V8.0.0 "Cellular text telephone modem; General description"
13 3GPP TS 26.268 V8.0.0 "Cellular text telephone modem; Transmitter bit exact C-code"

[4] The eCall System

Figure 2 illustrates parts of the eCall system. When a collision is detected by the IVS sensors in the vehicle, the IVS can be prompted by the user, or automatically, initiate an E112 emergency voice call. The emergency voice call is routed to the appropriate PSAP using the existing emergency routing procedures for voice E112 calls.

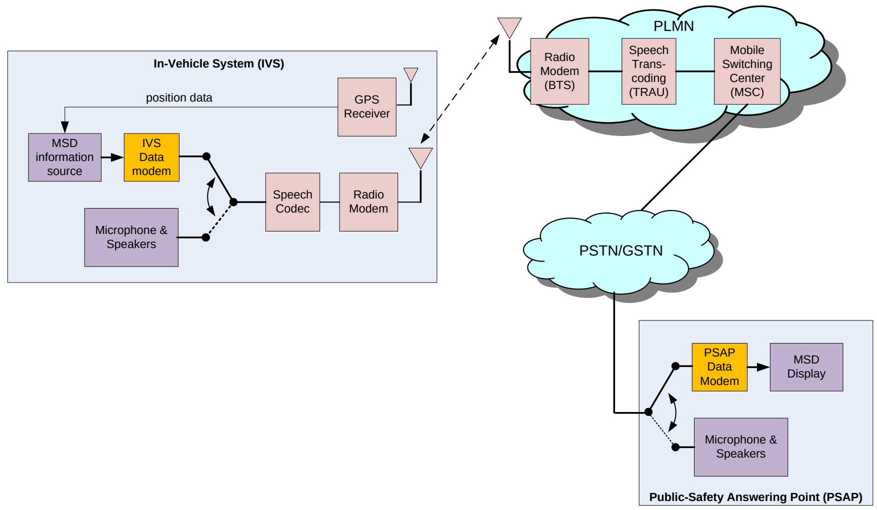

Figure 2. The eCall System

When triggered by a request from the PSAP operator through the PSAP modem, the in-band IVS data modem is used to transmit the relevant information (MSD) through the voice path established to the PSAP. Transmitting the MSD information through this voice path enables the system to use the E112 routing protocols deployed in existing networks.

The PSAP has a corresponding data modem to receive the transmission from the IVS and display the data to the PSAP operator.

[5] The eCall Data Modem

The eCall system uses an in-band data modem to transmit the MSD information over the voice path to the PSAP. This approach enables the eCall solution to be quickly deployed end-to-end in vehicle IVS's and PSAPs without modifications to the existing cellular and wireline infrastructure.

5.1 Transmission of MSD Information from IVS to PSAP

Figure 3 illustrates the eCall IVS data modem developed by Qualcomm. When prompted by a signal from the PSAP operator, the IVS connects the IVS data modem to the input of the speech codec and mutes any speech from the motorist for the duration of MSD transmission to prevent it from interfering with the eCall data transmission.

The MSD information input into the IVS data modem is first appended with Cyclic Redundancy Check (CRC) information. These bits are then encoded in the Hybrid-ARQ encoder using forward error correction (FEC) coding to reduce the susceptibility to transmission errors. The Hybrid-ARQ encoder employs a very powerful turbo encoding scheme with incremental redundancy added for each retransmission. The signal modulator converts the encoded data into waveform symbols which are especially suitable for transmission through all types of speech encoders employed in present mobile systems, including the GSM Full-Rate and the various modes of AMR encoders (12.2, 10.2, 7.95, 7.4, 6.7, 5.9, 5.15, and 4.75 kbps).

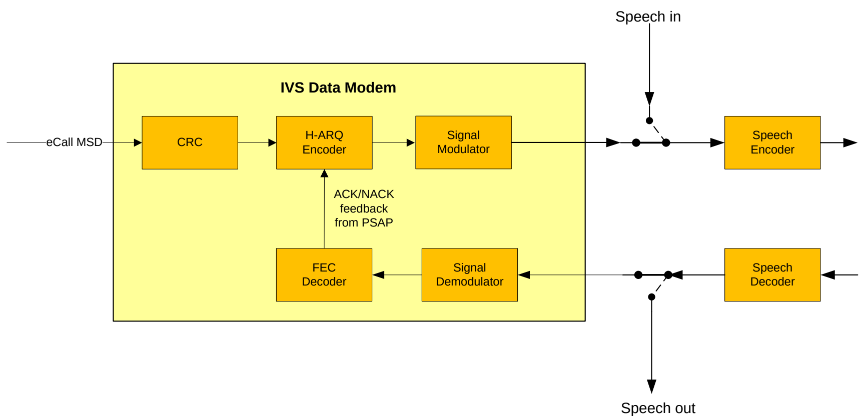

Figure 3. Structure of the proposed eCall IVS Data Modem

After transmission of the MSD information is completed, the eCall modems in both the IVS and PSAP return to idle state and the signal paths from the modems are switched off to avoid interference with the normal voice call.

Figure 4 illustrates the PSAP data modem developed by Qualcomm. The eCall PSAP receiver continuously monitors the incoming signal from the PSTN. When the eCall data signal is detected the outgoing speech path is muted and the signal demodulator detects the incoming data symbols. The H-ARQ decoder soft combines the first MSD transmission with any retransmissions of the information and decodes the FEC to determine the information bits, i.e., its estimate of the CRC protected MSD information. If a CRC error is detected, the PSAP receiver prompts the IVS transmitter to provide retransmissions with incremental redundancy. Otherwise, the MSD information is provided to the PSAP operator and the transmitter is notified that retransmissions are not or no longer required.

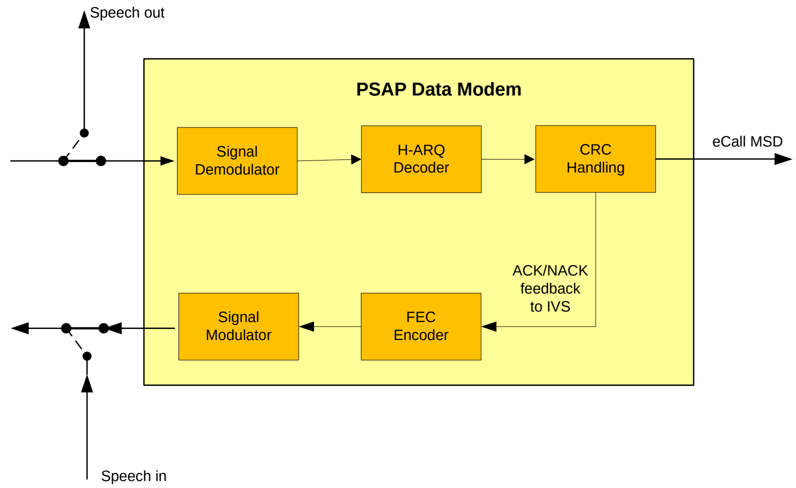

Figure 4. Structure of the proposed eCall PSAP Data Modem

5.2 Transmission of Control Messages from PSAP to IVS

Control messages are sent from the PSAP to the IVS to make the initial transmission request of the MSD information from the IVS and to provide ACK/NACK feedback for the H-ARQ mechanism.

The transmitter in the PSAP is similar to the transmitter in the IVS modem except that an H-ARQ mechanism is not used and a different FEC code is employed. The receiver in the IVS is also similar to the receiver in the IVS modem with the same exceptions of not employing the H-ARQ mechanism and using a different FEC code.

5.3 Performance of Qualcomm's eCall in-band data modem solution

The design of a digital data transmission scheme over a low-rate mobile radio voice communication channel represents a challenging engineering task due to the strongly non-linear characteristics of the channel.

Qualcomm's modem solution combines a newly developed, robust data modulator with a powerful error correction scheme. This provides strong protection against both distortion due to speech compression and transmission errors on the radio channel, and results in very reliable and robust transmission of the MSD information over the in-band voice channel. This very innovative data transmission scheme adapts itself efficiently to the voice codec in use and to the given radio channel conditions.

Under normal channel conditions, the MSD information is received at the PSAP in an average of 1.36 seconds, well below the 4 second requirement for the eCall in-band data modem. Low rate speech channels and bad radio conditions increase the overall MSD transmission time due to required retransmissions. However, even when including these less favorable conditions, the overall average transmission time of the Qualcomm modem across all required conditions is 2.03 seconds, still well below 4 seconds.

[6] 3GPP eCall Modem Selection

The European Commission and ETSI have delegated 3GPP to develop and standardize the eCall in-band modem solution[6] [7].

Qualcomm has been actively involved in the 3GPP eCall project. An engineering team in Qualcomm Germany has been leading the system development while a team in San Diego has been providing codec design aspects for an eCall in-band modem that meets the European Commission's requirements.

Qualcomm's solution was selected and endorsed by 3GPP as the standard eCall in-band modem at the SA#41 Plenary meetings held in Kobe, Japan, on September 15-18, 2008. As a result, 3GPP has approved the final specifications of the Qualcomm modem at the SA#43 Plenary meetings on March, 2009, in Biarritz, France. The two key specifications are:

- TS 26.267 "eCall Data Transfer - in-band modem solution; General Description" [8]

- TS 26.268 "eCall Data Transfer - in-band modem solution; ANSI-C Reference Code" [9]

Supplementary specifications and technical reports to describe the conformance requirements and performance characterization of compliant eCall implementations are scheduled to be completed by September, 2009.

[6] *3GPP TS 22.101 V9.0.0 "Service aspects; Service principles"*
[7] *3GPP TR 26.967 V8.0.1 "eCall Data Transfer; In-band modem solution"*
[8] *3GPP TS 26.267 V8.0.0 "Cellular text telephone modem; General description"*
[9] *3GPP TS 26.268 V8.0.0 "Cellular text telephone modem; Transmitter bit exact C-code"*

6.1 The Selection Process

The selection was made based on a competition held by the 3GPP SA Working Group 4 (SA4) evaluating the performance of three candidate modem solutions. A summary of this evaluation performed by an independent host laboratory is shown in Table 1 and illustrates how the Qualcomm solution (Candidate #3) achieves the fastest average transmission time by orders of magnitude. The number of timeouts indicates in how many test runs a candidate modem was unable to complete a successful transmission within 200 seconds. The details of these results are provided in [10].

	Unit	**Candidate 1 Airbiquity**	**Candidate 2 RIM**	**Candidate 3 Qualcomm**
Figure of Merit (avg. transmission time over all tested conditions)	Seconds	17.70	7.21	2.04
Number of Timeouts		5	0	0
Avg. transmission time in optimal conditions (error free radio channel, FR and AMR 12.2)	Seconds	3.60	3.12	1.36

Table 1: Summary of Independent Host Lab Selection Test Results

Figure 5 illustrates the performance of the three candidate modems across all the codec and channel conditions tested in the selection process. The figure illustrates how the Qualcomm modem (candidate 3) consistently outperforms the other candidates under all the conditions tested.

[10] 3GPP Tdoc SP-080474 "eCall Host Laboratory Test report (of the SelectionTest results obtained by each in-band modem candidate)"

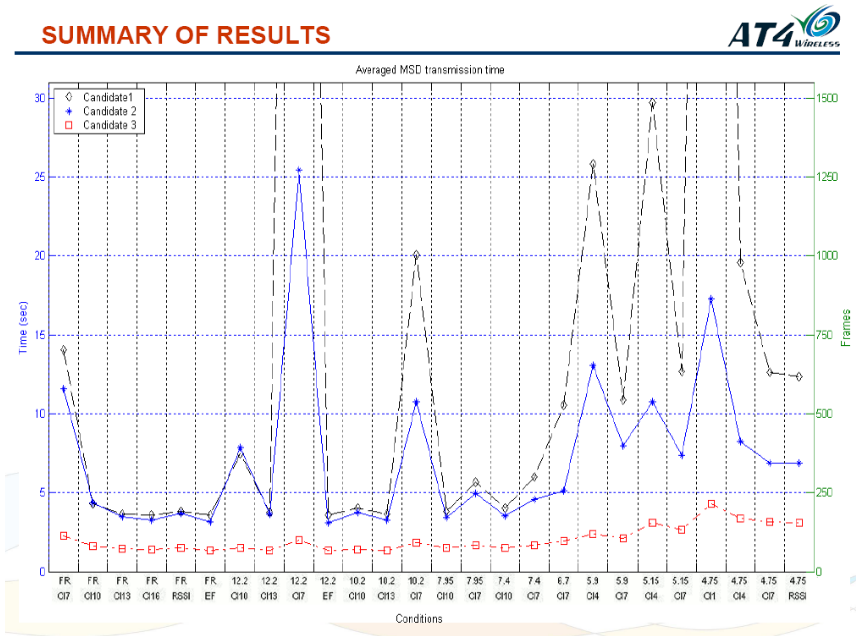

Figure 5. Average Transmission Time of Candidate Modems Across All Tested Codec and Channel Conditions (reprinted from11 with permission of AT4 Wireless)

[7] eCall Modem Complexity

As part of the 3GPP SA4 selection process, the selected candidate modem had to be subjected to testing and analysis by an independent host laboratory to evaluate the memory and computational complexity requirements of the modem. The results determined that the complexity of the Qualcomm modem design was well below the recommended design constraints determined by 3GPP SA4.

Table 2 below summarizes the RAM memory usage results for the optimized Qualcomm modem design standardized by 3GPP. This shows that the RAM memory usage on the IVS modem and PSAP modem are well below the recommended memory usage agreed in 3GPP SA4. The final optimized 3GPP implementation employs exactly the same algorithms and has the same performance as the prototype code tested in SA4 with the exception that its complexity and memory usage were significantly reduced.

[11] *3GPP Tdoc SP-080474 "eCall Host Laboratory Test report (of the SelectionTest results obtained by each in-band modem candidate)"*

	IVS	PSAP
Memory Usage (static & dynamic RAM, KBytes)	≈ 9.1	≈ 32.3
Recommended Memory Usage (KBytes)	< 20	< 40

Table 2: Summary of RAM Memory Usage of Qualcomm Modem[12] [13]

Table 3 below summarizes the computational complexity results for the final Qualcomm modem design, as standardized by 3GPP. The complexity evaluation is performed by comparing the execution time of the Qualcomm modem against the execution time of the reference CTM modem as specified in [14] [15]. The results show that the computational complexity of the Qualcomm IVS modem and PSAP modem are well below the computational complexity recommendations developed in 3GPP SA4.

	Complexity with respect to CTM (# times more computationally complex)	
Condition	**IVS**	**PSAP**
Official test campaign[16] **(AMR, GSM-FR; various C/I conditions)**	0.32	2.49
Recommended Computational Complexity (# times CTM)	< 10	< 20

Table 3: Summary of Computational Complexity of Qualcomm Modem (as standardized by 3GPP[17] [18]*)*

The final 3GPP implementation of the Qualcomm modem exhibits a complexity that is either less than, or similar to, the other two candidate solutions that were considered in 3GPP SA4, while achieving superior performance in terms of average MSD transmission times which are reproduced in Table 4.

[12] 3GPP TS 26.267 V8.0.0 "Cellular text telephone modem; General description"
[13] 3GPP TS 26.268 V8.0.0 "Cellular text telephone modem; Transmitter bit exact C-code"
[14] 3GPP TS 26.226 V8.0.0 "Cellular text telephone modem; General description"
[15] 3GPP TS 26.230 V7.1.0 "Cellular text telephone modem; Transmitter bit exact C-code"
[16] 3GPP Tdoc SP-080474 "eCall Host Laboratory Test report (of the SelectionTest results obtained by each in-band modem candidate)"
[17] 3GPP TS 26.267 V8.0.0 "Cellular text telephone modem; General description"
[18] 3GPP TS 26.268 V8.0.0 "Cellular text telephone modem; Transmitter bit exact C-code"

Condition	Qualcomm MSD Tx time (final 3GPP version)	Candidate 1 MSD Tx time (selection test)	Candidate 2 MSD Tx time (selection test)
AMR 12.2 Error Free	1.35 s	3.61 s	3.11 s
AMR 12.2 C/I=7dB	1.91 s	113.97 s	25.43 s
AMR 4.75 C/I=4dB	3.38 s	19.61 s	8.22 s
Official test campaign[19]	2.03 s	17.70 s	7.21 s

Table 4 Comparison of MSD Transmission Times

The details of the memory and complexity analysis performed by the independent host laboratory are provided in[20]. Note that all these evaluations were performed on an initial prototype implementation provided by Qualcomm for the eCall competition. This optimized version of the code significantly reduces the memory and complexity requirements. This optimized version can be further simplified in actual product implementations.

[8] Licensing

8.1 PSAP Equipment

In recognition of the important public safety aspects of this work and to accelerate the deployment of the eCall solution, subject to certain standard terms and conditions (e.g., protection for Qualcomm products as to the licensees or its customers patents), Qualcomm will not charge royalties for the implementation of Qualcomm patents essential to the 3GPP eCall in-band modem standard (3GPP TS 26.267 and TS 26.268) on sales of in-band voice-channel modem equipment that implements such standard and is located in the PSAP or core network, but solely when and to the extent such equipment is used for emergency communications. Qualcomm will offer to grant licenses on terms and conditions that are fair, reasonable and free from unfair discrimination for the use of such equipment for non-emergency communications.

[19] *3GPP Tdoc SP-080474 "eCall Host Laboratory Test report (of the SelectionTest results obtained by each in-band modem candidate)"*

[20] *"Additional Testing for the Selection of an In-band Modem Software for Transmission of eCall Data During Emergency Calls," from AT4 Wireless s attachment to 3GPP Tdoc SP-080467 "TSG-SA WG4 (SA4) Status Report at TSG-SA#41".*

8.2 In-Vehicle System Devices

Subject to certain standard terms and conditions (e.g., protection for Qualcomm products as to the licensees or its customers patents), Qualcomm will not charge a royalty rate for a license for its patents essential to the 3GPP eCall in-band modem standard (3GPP TS 26.267 and TS 26.268) in subscriber devices that implement such modem standard that is higher than the royalty rate that Qualcomm charges, or may in the future charge, for a license under its applicable patents for similar devices that do not implement such modem standard. For clarity, the 3GPP eCall in-band modem standard does not include cellular modem functionality or any other functionality in a handset or device.

For further information on these licensing terms please contact Mr. Luke Bonacci at lbonacci@qualcomm.com.

[9] Productization

Qualcomm's wireless chips are currently being used as the principal communications engine in millions of commercially deployed automotive telecommunications units.

As a leader in developing, delivering, and enabling innovative digital wireless communications products and services, Qualcomm is in a unique position to provide robust, reliable, and commercially viable eCall chipset solutions and products for a pan-European eCall standard.