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TECHNICAL REPORT

Report No.:
28522IDT.002

REPORT ON: ADITIONAL TESTING FOR THE SELECTION OF AN IN-BAND MODEM SOFTWARE FOR TRANSMISSION OF ECALL DATA DURING EMERGENCY CALLS

Product	:	Source C-Code files
Trade Mark	:	N/A
Model	:	N/A
Manufacturer	:	QUALCOMM INCORPORATED
Requested by	:	QUALCOMM INCORPORATED
Reference Documents(s)	:	Tdoc S4-080595: eCall Remaining Selection and Verification Phase Item (Permanent Document PD6: v 1.0)

The total number of pages of this report is 12.

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1. INTENDED AUDIENCE

This document is targetted to the 3GPP SA Working Group #4 (Codecs), mainly to the partners involved in the eCall Subworking Group.

This report is the result of the verification of a set of remaining selection items for an eCall in-band modem software solution, under the scope of the European eSafety initiative.

2. COMPETENCE AND GUARANTEES

AT4 wireless is a testing laboratory competent to carry out the tests described in this report.

In order to assure the traceability to other national and international laboratories, AT4 wireless has a calibration and maintenance programme for its measurement equipment.

AT4 wireless guarantees the reliability of the data presented in this report, which is the result of the measurements and the tests performed to the item under test on the date and under the conditions stated on the report and, it is based on the knowledge and technical facilities available at AT4 wireless at the time of performance of the test.

AT4 wireless is liable to the client for the maintenance of the confidentiality of all information related to the item under test and the results of the test.

3. GENERAL CONDITIONS

1. This report is only referred to the item that has undergone the test.
2. This report does not constitute or imply on its own an approval of the product by the Certification Bodies or competent Authorities.
3. This document is only valid if complete; no partial reproduction can be made without previous written permission of AT4 wireless.
4. This test report cannot be used partially or in full for publicity and/or promotional purposes without previous written permission of AT4 wireless and the Accreditation Bodies.

4. CHARACTERISTICS OF ECALL TESTING

4.1. SERVICES REQUESTED

AT4 wireless contributes in SA4 Working group providing eCall testing and verification services for the eCall candidates.

The service requested is to evaluate an eCall candidate modem solution as per [1], verifying a list of items in order to complete the Selection Test Phase. These items have been agreed by the eCall SWG during the SA4#50 meeting, and are described in [1], table 1a.

As per requested by the manufacturer, before compiling the source code provided, the following constants have been modified in the file *ecall_defines.h*

```
#define LLR 0
#define BUGFIX 0
```

To the following values:

```
#define LLR 1
#define BUGFIX 1
```

There is no standard method or specification to evaluate the requested items. Hence the procedures followed for the evaluation of the different eCall solutions have been those described in [2] and also agreed by the eCall group members in email discussions.

This test report is not an official report for Accreditation Bodies.

4.2. ECALL REQUIREMENTS AND METHODS

The tests have been carried out according to the following documents:

[1] Tdoc S4-080595: PD6, v1.0, eCall Remaining Selection and Verification Phase Item
[2] Tdoc S4-080584: PD6, Annex A, Remaining eCall selection item test requirements and procedures.

Additionally, the following documents gather information related to the execution of the tests and requirements, as well as related information used for this report:

[3] Tdoc S4-080446: PD3, v1.2, eCall Phase 2 Selection Test Plan
[4] Tdoc S4 080445: PD5, v1.0. Definition of Host Lab Tasks for eCall Selection Tests
[5] Tdoc S4-080597 eCall Phase 2 Timeplan (Permanent Document PD1: Version 1.1)
[6] Tdoc S4-080424: PD2, v1.2, Performance Requirements/Objectives and Design Constraints
[7] Tdoc S4-080532: PD4, v1.1, eCall Phase 2 Selection Rules
[8] Tdoc S4-080582: Test set-up used for the eCall selection phase
[9] Tdoc S4-080489: eCall Host Lab Test report
[10] Tdoc S4-080581: Meeting Report of eCall SWG during SA4#50
[11] Tdoc S4-070412: eCall via CTM ARQ analysis.

The following requirements and objectives evaluated for this report have been extracted from the above document [1], table 1a “Remaining Selection Phase items”, and are copied hereby:

- **Item 1: Source Code**. The source code provided for the remaining Selection Phase items shall produce the same results as in the selection test.

- **Item 2: CRC**. The MSD shall be transmitted reliably to the PSAP. An MSD transmission is considered reliably terminated, if a cyclic redundancy check (CRC) of at least 28 bits, applied to the entire MSD, detects no errors.

- **Item 4: Data Memory**. The candidate algorithm as implemented in the IVS should not require more than 20KB of data memory. The candidate algorithm as implemented in the PSAP should not require more than 40KB of data memory.
  The memory requirements are estimated by inspection of the C-Codes.

- **Item 5: Complexity**. The candidate algorithm as implemented in the IVS should not have more than 10 times the complexity of CTM. The candidate algorithm as implemented in the PSAP should not have more than 20 times the complexity of CTM.
  The complexity is estimated by compiling the C-Codes under similar compiler conditions and then measuring the processing times.

Note: As per [1], there is an additional item included in table 1a:

Item 3: *The candidate algorithm shall be able to run in real-time on the Host Lab setup.*
Note: The real-time clock is based on the input and output of the audio buffers through the host controller. This time is logged. The sum of these logged times over all the test configurations and trials per configuration (total of 2600) shall be compared to the sum of the corresponding execution times.

However, in [1] is also stated that this requirement is considered as satified and does not need to be further studied. Hence, it has not been included in this report.

4.3. ECALL TEST SETUP, INSTRUMENTATION AND CONFIGURATION

The same test setup instrumentation and configuration used during the Selection Phase, described in [8] has been used (when needed) during the verification of the items whose results are included in this report.
This test setup is composed of three Personal Computers with Intel Core 2 Duo processors and Windows XP Operation System, connected through an Ethernet Switch. The PC's acting as IVS and PSAP include a Firewall configured to block all traffic (incoming and outgoing) between IVS and PSAP IP's, but allowing the control PC to communicate either one.

The simulation done for verification of item 5 (Complexity) has been done using only 1 of those PCs.

4.4. TESTING PERIOD

The testing period started on September 17, 2008 and finished on September 18, 2008.
The tests have been performed at AT4 wireless permanent facilities.

5. VERIFICATION PROCEDURES AND RESULTS

The following items have been studied, and the results are presented for the eCall modem tested in this report:

5.1. ITEM 1: SOURCE CODE

Requirement:

Source Code verification. The source code provided for the remaining Selection Phase items in this table shall produce the same results as in the selection test.

Procedure:

The modem software source code received from the candidate has been built by AT4 wireless, changing the two constant values described in "Service Requested" paragraph.
The executable file obtained from this compilation has been run on the selection test platform using the same test configuration file (official test campaign) used during the selection test phase.
The output file obtained after running the official test campaign with this executable file is compared to the output file generated during the selection test phase.

Result:

The comparison of the output file obtained during the selection test phase and the one obtained with the executable file compiled by AT4 wireless shows 38 differences out of the 2600 test cases of the official test campaign used in [9]. A table with such differences is shown below:

Index	Codec	VAD	Error Patern	Time (in frames) of modem candidate 3 tested in [9]	Time (in frames) of modem tested in this report	Relative Error %
177	fr	1	fr-na-ci10.if1	103	85	-17,48%
56	fr	2	fr-na-ci7.if1	186	84	-54,84%
2462	amr 4.75	1	amr-4_75-ci7.if1	191	209	9,42%
2470	amr 4.75	2	amr-4_75-ci7.if1	174	156	-10,34%
713	amr 12.2	2	amr-12_2-ci13.if1	103	85	-17,48%
344	fr	2	fr-na-ci16.if1	67	84	25,37%
2267	amr 4.75	2	amr-4_75-ci1.if1	208	190	-8,65%
2224	amr 4.75	1	amr-4_75-ci1.if1	190	173	-8,95%
345	fr	1	fr-na-ci16.if1	84	67	-20,24%
153	fr	1	fr-na-ci10.if1	120	84	-30,00%
1212	amr 10.2	2	amr-10_2-ci7.if1	85	103	21,18%
2114	amr 5.15	2	amr-5_15-ci7.if1	137	155	13,14%
1056	amr 10.2	1	amr-10_2-ci10.if1	84	67	-20,24%
817	amr 12.2	2	amr-12_2-ci7.if1	103	85	-17,48%

1899	amr 5.9	2	amr-5_9-ci4.if1	120	102	-15,00%
94	fr	1	fr-na-ci7.if1	120	102	-15,00%
2443	amr 4.75	2	amr-4_75-ci7.if1	156	138	-11,54%
2511	amr 4.75	2	amr-4_75-rssi100.if1	174	156	-10,34%
160	fr	2	fr-na-ci10.if1	102	84	-17,65%
1889	amr 5.9	2	amr-5_9-ci4.if1	121	103	-14,88%
175	fr	1	fr-na-ci10.if1	84	67	-20,24%
1617	amr 7.4	2	amr-7_4-ci7.if1	68	85	25,00%
2418	amr 4.75	2	amr-4_75-ci7.if1	155	137	-11,61%
2227	amr 4.75	2	amr-4_75-ci1.if1	209	191	-8,61%
2553	amr 4.75	1	amr-4_75-rssi100.if1	191	174	-8,90%
2420	amr 4.75	2	amr-4_75-ci7.if1	157	139	-11,46%
889	amr 12.2	2	amr-12_2-ci7.if1	85	103	21,18%
2331	amr 4.75	2	amr-4_75-ci4.if1	173	155	-10,40%
2489	amr 4.75	2	amr-4_75-ci7.if1	156	138	-11,54%
33	fr	1	fr-na-ci7.if1	102	168	64,71%
2433	amr 4.75	2	amr-4_75-ci7.if1	138	121	-12,32%
407	fr	2	fr-na-rssi100.if1	103	85	-17,48%
2298	amr 4.75	2	amr-4_75-ci1.if1	208	190	-8,65%
93	fr	1	fr-na-ci7.if1	120	102	-15,00%
1663	amr 7.4	1	amr-7_4-ci7.if1	67	84	25,37%
2059	amr 5.15	1	amr-5_15-ci4.if1	174	156	-10,34%
2040	amr 5.15	1	amr-5_15-ci4.if1	260	138	-46,92%
2095	amr 5.15	1	amr-5_15-ci4.if1	191	174	-8,90%

Table 1: Differences found between eCall modem Candidate 3 tested in [9] and modem tested in this report.

Because of the differences extracted from the comparison of both files, the tested modem cannot be considered bit-exact the same that was tested during the selection phase, whose results are included in [9].
Therefore, the tested modem is NOT IN COMPLIANCE with Item 1 requirement.

However, due to such differences, a comparison of the main figures obtained in [9], and the ones obtained with this modem has been made: Figure of Merit, Number of Timeouts, Incorrect MSD's reported, and timings for the time to transmit the MSD in error free conditions. This comparison is stated in the table below:

Summary of results for both modems							
	Unit	**Candidate 3 results [9]**			**Modem tested in this report**		
Figure of Merit	Frames	**101,85**			**101,64**		
	Seconds	**2,04**			**2,03**		
Number of timeouts		**0**			**0**		
Incorrect MSD's reported		**0**			**0**		
Average time in Optimal conditions (Error free radio channel, FR and AMR 12.2 codecs)	Seconds	**1,36**			**1,36**		
Error free: FR codec tmin/tmax/average	Seconds	**1,34**	**1,7**	**1,36**	**1,34**	**1,7**	**1,35**
Error free: AMR 12.2 codec tmin/tmax/average	Seconds	**1,34**	**1,38**	**1,35**	**1,34**	**1,38**	**1,36**

Table 2: Comparisons of figures: Candidate 3 results vs this modem results

5.2. ITEM 2: CRC

Requirement:

CRC verification. The MSD shall be transmitted reliably to the PSAP. An MSD transmission is considered reliably terminated, if a cyclic redundancy check (CRC) of at least 28 bits, applied to the entire MSD, detects no errors.

Procedure:

Source code inspection.

Result:

The CRC is defined in the file "*eCall_fec.c*" (line 237) in a function called "*crc_decode*". It has been checked by inspection of the code that it is a 28-bit CRC.

Hence, the tested modem is IN COMPLIANCE with Item 2 requirement.

5.3. ITEM 4: DATA MEMORY

Requirement:

Data Memory. The candidate algorithm as implemented in the IVS should not require more than 20KB of data memory. The candidate algorithm as implemented in the PSAP should not require more than 40KB of data memory.
The memory requirements are estimated by inspection of the C-Codes.

Procedure:

Memory for data only is considered, including static and global variables, constants, and maximum amount of instantaneous dynamically allocated memory. Code memory and ROM tables are not counted.

In order to obtain the static memory and maximum simultaneus dynamically allocated memory, the code has been traced. It should be noted that this memory includes pointers, which will be dependant on compiler and platform of execution. Although the memory used for pointers depends on compiler, it's a very low value compared to the rest of figures.

Word8 variables and arrays cells have been counted as 1 byte, word16 as 2 bytes, and word32 as 4 bytes each.

Result:

For IVS:

The total Static memory allocation is **7016 bytes**.

The maximum ammount of dynamically allocated memory is **1039 bytes**

Hence, the total memory required by the IVS is **8055 bytes.**

For PSAP:

The total Static memory allocation is **13214 bytes**.

The maximum ammount of dynamically allocated memory is **18586 bytes** (this figure includes 56 bytes of pointers).

Hence, the total memory required by the PSAP is **31800 bytes.**

Hence, the tested modem is IN COMPLIANCE with Item 4 requirement.

5.4. ITEM 5: COMPLEXITY

Requirement:

Complexity verification. The candidate algorithm as implemented in the IVS should not have more than 10 times the complexity of CTM. The candidate algorithm as implemented in the PSAP should not have more than 20 times the complexity of CTM.
The complexity is estimated by compiling the C-Codes under similar compiler conditions and then measuring the processing times.

Procedure:

The procedure is to measure the complexity by recording the execution times in comparison to CTM modem.

The following set of representative channel conditions have been elected for this evaluation:

Codec AMR 12.2kbps, in Error free channel condition
Codec AMR 12.2kbps, with C/I=7dB channel condition
Codec AMR 4.75kbps, with C/I=4dB channel condition

Test campaigns composed of 500 test cases have been used for each of the three codec/channel conditions, making a total of 1500 test cases. Random MSD, delays and index for error patterns have been used. VAD has been fixed set to 1.

The calculation of the number of retransmissions for CTM modem is extracted from [11], Tdoc S4-070412: eCall via CTM ARQ analysis, in which the performance of CTM operating as an eCall modem in the above channel conditions is provided. The number of retransmits for CTM for the following channels will result in successful MSD transmission in 99,998% of the cases.
For error-free channel, zero retransmissions are required.
For AMR FR 4.75 vocoder, with C/I=4dB, the calculated number of retransmissions is 1.
For AMR FR 12.2 vocoder, with C/I=7dB, the calculated number of retransmissions is 2.

Two metrics are calculated and reported for CTM and the eCall tested modem:

1. **Metric 1**: The average execution time of the Rx/Tx process to process a 20 msec audio buffer. The goal of this metric is to obtain a measure of processing load (complexity).

2. **Metric 2**: The execution time normalized by the number of successfully transmitted frames. This can be also considered as a metric of efficiency.

For metric 1:

- Steps for testing the execution time of the *eCall modem*:

  a) Compile the eCall source code for the test set-up used in the selection phase.
  b) Run this executable on the test set-up for each of the above channel conditions.
  c) For each of those conditions, a test campaign with 500 test cases shall be used, as specified above.
  d) Record the PCM data input to the IVS and PSAP demodulators in files. This is done in the control PC by adding an option to the executable call.
  e) Compile the modem source code provided for operating on the PCM files ('speedtest.c').
  f) Record the execution times of the IVS and PSAP separately when operating on the PCM data. Exclude the file I/O time in the execution time. Measuring of execution times is started after the first 50 idle frames (transmitted to initialize the codecs in the test setup). All of this is done by the executable file obtained in e).
  g) Divide the total execution time by the number of 20ms frames processed during measurement to obtain metric 1. This task is also done by the executable file obtained in e).

- Steps for testing the execution time of the *CTM modem*:

  a) Compile and run the CTM code as in the reference code (to keep things simple no ARQ mechanism needs to be added to the CTM code). The CTM code compiled has not been the standard one included in 3GPP 26.230_v7.1.0, but a different one slightly modified to be able to get timing measurements. This source files have been provided by the manufacturer of the eCall modem, stated in Page 1.
  b) Measure the execution time without counting any file I/O times. Also, measuring execution times have not started until the modem is fully operating in transmit and receive mode (the modulator and demodulator need to both be running in the IVS and PSAP).
  c) Divide the total execution time by the number of 20ms frames processed during measurement to obtain metric 1.

The complexity of the eCall modem compared to the CTM one (in times) is calculated by dividing both figures obtained, for each channel condition.

For Metric 2:

Metric 2 is just a simple calculation of the execution time normalized by the number of successfully transmitted frames. Hence, this metric is derived directly from Metric1:

For the *eCall modem*:
Metric 2 = Metric 1 (in seconds/frame) * 50 (frames/second) * average time to transmit MSD for the selected condition (in seconds).
For *CTM modem*:
Metric 2 = Metric 1 (seconds/frame) * 50 (frames/second) * average time to transmit equivalent number of bits of a MSD (in seconds).

The average time to transmit the MSD for the selected conditions is calculated as in [9] for the eCall modem, and the values for CTM can be obtained from [11], and stated hereby:
It must be noted that as the test results obtained in item 1 are different from the ones obtained in the selection tests, the average values for the below conditions have been recalculated for this modem. However, the calculated average values for the 3 channel/codec conditions have been identical (rounding to 2 decimals).

Channel/Codec Condition	eCall Candidate modem	CTM
AMR 12.2 Error Free	1.35 seconds	29 seconds
AMR 12.2 C/I=7dB	1.97 seconds	41.2 seconds
AMR 4.75 C/I=4dB	3.36 seconds	35.1 seconds

Table 3: average time to transmit MSD

Results

Results for Metric 1:

IVS vs CTM: Metric 1			
	Condition	**Average processing time per frame (msecs)**	**Complexity with respect CTM (times)**
CTM modem		0,107	---
eCall Modem	AMR 12.2 Error Free	0,260	**2,43**
	AMR 12.2 C/I=7dB	0,223	**2,08**
	AMR 4.75 C/I=4dB	0,151	**1,41**

Table 4: Comparison of metric 1 (IVS vs CTM)

PSAP vs CTM: Metric 1			
	Condition	**Average processing time per frame (msecs)**	**Complexity with respect CTM (times)**
CTM modem		0,107	---
eCall Modem	AMR 12.2 Error Free	0,200	**1,87**
	AMR 12.2 C/I=7dB	0,367	**3,43**
	AMR 4.75 C/I=4dB	0,554	**5,18**

Table 5: Comparison of metric 1 (PSAP vs CTM)

From table 4, it can be checked in the last column that the maximum complexity of the eCall modem algorithm for the IVS is **2.43** times the complexity of the CTM modem.

From table 5, it can be checked in the last column that the maximum complexity of the eCall modem algorithm for the PSAP is **5.18** times the complexity of the CTM modem.

Hence, the eCall tested modem is IN COMPLIANCE with Item 5 requirement, taking the Metric 1 as the requirement of this item.

Results for Metric 2:

The following table is obtained following the procedure described above for calculating metric 2:

eCall Modem vs CTM: Metric 2					
	Condition	**Metric 1 (processing time per frame - msecs)**	**Frames per second**	**Time to transmit MSD (seconds)**	**Average processing time per MSD (msecs)**
CTM modem	AMR 12.2 Error Free	0,107	50	29	155,15
	AMR 12.2 C/I=7dB	0,107	50	41,2	220,42
	AMR 4.75 C/I=4dB	0,107	50	35,1	187,79
eCall Modem - IVS	AMR 12.2 Error Free	0,260	50	1,35	17,55
	AMR 12.2 C/I=7dB	0,223	50	1,97	21,97
	AMR 4.75 C/I=4dB	0,151	50	3,36	25,37
eCall Modem - PSAP	AMR 12.2 Error Free	0,200	50	1,35	13,50
	AMR 12.2 C/I=7dB	0,367	50	1,97	36,15
	AMR 4.75 C/I=4dB	0,554	50	3,36	93,07

Table 6: Comparison of metric 2

As it can be extracted from table 6, taking metric2 as the complexity calculation of each modem for the three channel/vocoder conditions, it is checked that the complexity of the eCall modem is always less than the complexity of the CTM modem.

6. SUMMARY

The source code provided by the manufacturer has ben evaluated against the 4 remaining items identified in table 1a of document [1]. The following results have been obtained:

Item 1: Source Code. **NOT IN COMPLIANCE**.

Item 2: CRC: **IN COMPLIANCE**

Item 4: Data Memory: **IN COMPLIANCE**

Item 5: Complexity: **IN COMPLIANCE**.

Hence, this modem is **NOT IN COMPLIANCE** with all the requirements mentioned in document [1] table 1a, following the procedures of evaluation described in this report.

7. REMARKS AND COMMENTS

None.