C8 Structure and Format Analysis of Lossy Compressed Audio Files

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After attending this presentation, attendees will have a better understanding of multimedia metadata analysis and how it can benefit investigations which audio authenticity and source attribution are important questions.

This presentation will impact the forensic science community by revealing the latest results in a large study of digital audio recordings that are lossy compressed such as MPEG-1 and/or MPEG-2 Audio Layer III (MP3), Advanced Audio Coding (AAC), and more.

This presentation introduces a study on the format and structure of digital audio files, with an emphasis on lossy compression algorithms like MP3, Windows® Media Audio (WMA), and AAC. Lossy compressed audio files are common in real forensic cases, can be produced with digital audio recorders, digital video cameras, mobile phones, tablets, computers, and other digital systems, and their forensic authentication can be crucial in the courtroom or other extrajudicial investigations. As was presented at the 2016 AAFS Annual Scientific Meeting, in conjunction with other analyses largely involving time and frequency domain measurements/plots (e.g., Quantization Levels/Bit Depth, Long-Term Average Spectrum, Modified Discrete Cosine Transform coefficients, etc.), a framework for digital audio authentication includes analysis of the file structure and format as well as investigation of the suspected recording device itself, when available.[1-3] Previous papers presented the results of MP3 and WMA digital lossy audio format analysis for forensic purposes.[4,5] This study reports an investigation of more than 50 different digital audio recorders and mobile phones from over ten years of data collection, validates the previously mentioned studies on MP3 and WMA, and extends the research on iPhones recordings and AAC files as well. In the interest of authentication and establishing digital provenance of recordings, examples of traces left by different digital audio editors (e.g., Adobe® Audition, GoldWave, Sound Forge™ Pro) and converters (e.g., ffmpeg) are also presented.

Preliminary results indicate that while, in most of the cases, the original files contain references of the make, model, recording timestamp, and/or OS version, the digital lossy recompression process affects files' headers and removes this information. The following tables illustrate different examples of the structure analysis results for: original MP3 and WMA files from Olympus® and Sony recorders; original AAC files from different iPhone® OS versions; and digital audio converted/edited MP3, WMA, and AAC files. The conclusion of this study is that structure analysis can be very effective in forensic audio authentication. It can be used to: (1) reveal similarities or inconsistencies between evidence and original reference recordings produced with the suspect digital audio recording system; (2) to verify the evidence file(s) against original reference recordings created with the suspect recorder or another same make and model device; and, (3) to identify the recording system when a database of original recordings is maintained and available.

The following tables provide examples of the material and results collected in this study.

Table 1. MP3

OLYMPUS®VN-5200PC, VN-8100PC	OLYMPUS® DM-7, VP-10	OLYMPUS® DM-520	SONY ICD-UX533	Adobe® Audition MP3 edited file
Ofs: 0 -> ID3 Ofs: A -> XOLY Ofs: 15 -> dss Ofs: 20 -> *model* Ofs: 3A -> *timestamp*	Ofs: 0 -> ID3 Ofs: A -> XOLY Ofs: 15 -> mp3 Ofs: 20 -> *model* Ofs: 3A -> *timestamp*	No make, model, timestamp, or ID3 tag	Ofs: 0 -> ID3 Ofs: A -> GEOB Ofs: 17 -> SfMarkers Ofs: AE5 -> GEOB Ofs: AF2 -> IcdRInfo Ofs: AF6 -> Info Ofs: B00 -> ICDUX533 Ofs: B35 -> TIT2 Ofs: B4B -> TPE1 Ofs: B72 -> TENC Ofs: B7D -> SONY IC RECORDER MP3	Ofs: 0 -> ID3 Ofs: A -> TCON

Table 2. WMA

OLYMPUS® DM-520, VN-722PC, WS-822 8KHz, 8kbps, mono	OLYMPUS® DM-520, WS-550M, WS-560M 22KHz, 32kbps, stereo	OLYMPUS® DM-520, DM-620, LS10, WS-210S, WS-311M, WS-750M, WS-760M 44KHz, 128kbps, stereo	Adobe Audition WMA edited file
Ofs: 0 -> 0&² Ofs: 3A -> OLYMPUS® Ofs: 4F -> dss Ofs: 5A -> *model* Ofs: 568 -> Windows® Media Audio V8 Ofs: 59C -> 8kbps Ofs: 5AE -> 8kHz Ofs: 5BC -> mono Ofs: 74 -> *timestamp*	0 -> 0&² 3A -> OLYMPUS® 4F -> dss 5A -> *model* 568 -> Windows® Media Audio V8 59A -> 16kbps 5AC -> 22kHz 5BC -> mono 74 -> *timestamp*	0 -> 0&² 3A -> OLYMPUS® 4F -> dss 5A -> *model* 568 -> Windows® Media Audio V8 598 -> 128kbps 5AC -> 44kHz 5BC -> stereo 74 -> *timestamp*	0 -> 0&² 40 -> Tool Name 56 -> Adobe® Audition 78 -> WMAFilter 96 -> ToolVersion CA -> WMFSDKVersion 10C -> WMFSDKNeeded 142 -> IsVBR 253 -> IsVBR 26D -> DeviceConformanceTemplate 130B -> 128kbps 131F -> 44kHz 1355 -> passCBR

Table 3. AAC (iPhones®)

OS 7.1.1	**OS 8.0.2**	**OS 8.4.1**	**OS 9.2**	**Adobe® Audition AAC edited file**
Ofs: 4 -> ftyp	Ofs: 4 -> ftyp	Ofs: 4 -> ftyp	Ofs: 4 -> ftyp	Ofs: 4 -> ftyp
Ofs: 8 -> M4A	Ofs: 8 -> M4A	Ofs: 8 -> M4A	Ofs: 8 -> M4A	Ofs: 8 -> mp42
Ofs: 10 -> M4A	Ofs: 10 -> M4A	Ofs: 10 -> M4A	Ofs: 10 -> M4A	Ofs: 10 -> mp42
Ofs: 14 -> mp42	Ofs: 14 -> mp42	Ofs: 14 -> mp42	Ofs: 14 -> mp42	Ofs: 14 -> isom
Ofs: 18 -> isom	Ofs: 18 -> isom	Ofs: 18 -> isom	Ofs: 18 -> isom	Ofs: 97331 -> moov
Ofs: 20 -> wide	Ofs: 20 -> wide	Ofs: 20 -> wide	Ofs: 20 -> wide	Ofs: 97338 -> lmvhd
Ofs: 8B495 -> moov	Ofs: 14808 -> moov	Ofs: 24FDD1 -> moov	Ofs: 1644B -> moov	Ofs: 973BD -> trak
Ofs: 8B49C -> lmvhd	Ofs: 1480F -> lmvhd	Ofs: 24FDD8 -> lmvhd	Ofs: 16452 -> lmvhd	Ofs: 973C5 -> tkhd
Ofs: 8B509 -> trak	Ofs: 1487C -> trak	Ofs: 24FE45 -> trak	Ofs: 164BF -> trak	Ofs: 97421 -> mdia
Ofs: 8B511 -> tkhd	Ofs: 14884 -> tkhd	Ofs: 24FE4D -> tkhd	Ofs: 164C7 -> tkhd	Ofs: 97429 -> mdhd
Ofs: 8B56D -> mdia	Ofs: 148E0 -> mdia	Ofs: 24FEA9 -> mdia	Ofs: 16523 -> mdia	Ofs: 97449 -> hdlr
Ofs: 8B575 -> mdhd	Ofs: 148E8 -> mdhd	Ofs: 24FEB1 -> mdhd	Ofs: 1652B -> mdhd	Ofs: 97455 -> soun
Ofs: 8B594 -> 1hdlr	Ofs: 14907 -> 1hdlr	Ofs: 24FED0 -> 1hdlr	Ofs: 1654A -> 1hdlr	Ofs: 9746A -> minf
Ofs: 8B595 -> hdlr	Ofs: 14908 -> hdlr	Ofs: 24FED1 -> hdlr	Ofs: 1654B -> hdlr	Ofs: 97472 -> smhd
Ofs: 8B5A1 -> soun	Ofs: 14914 -> soun	Ofs: 24FEDD -> soun	Ofs: 16557 -> soun	Ofs: 97482 -> dinf
Ofs: 8B5B1 -> CoreMediaAudio	Ofs: 14924 -> CoreMediaAudio	Ofs: 24FEED -> CoreMediaAudio	Ofs: 16567 -> CoreMediaAudio	Ofs: 9748A -> dref Ofs: 9749A -> url
Ofs: 8B5C6 -> minf	Ofs: 14939 -> minf	Ofs: 24FF02 -> minf	Ofs: 1657C -> minf	Ofs: 974A6 -> stbl
Ofs: 8B5CE -> smhd	Ofs: 14941 -> smhd	Ofs: 24FF0A -> smhd	Ofs: 16584 -> smhd	Ofs: 974AD -> gstsd
Ofs: 8B5DE -> dinf	Ofs: 14951 -> dinf	Ofs: 24FF1A -> dinf	Ofs: 16594 -> dinf	Ofs: 974AE -> stsd
Ofs: 8B5E6 -> dref	Ofs: 14959 -> dref	Ofs: 24FF22 -> dref	Ofs: 1659C -> dref	Ofs: 974BE -> mp4a
Ofs: 8B5F6 -> url	Ofs: 14969 -> url	Ofs: 24FF32 -> url	Ofs: 165AC -> url	Ofs: 974E2 -> esds

OS 7.1.1	OS 8.0.2	OS 8.4.1	OS 9.2	Adobe® Audition AAC edited file
Ofs: 8B602 -> stbl Ofs: 8B609 -> gstsd Ofs: 8B60A -> stsd Ofs: 8B61A -> mp4a Ofs: 8B63E -> esds Ofs: 8B671 -> stts Ofs: 8B689 -> stsc Ofs: 8B6A5 -> stsz Ofs: 8E78D -> stco Ofs: 8E7A9 -> meta Ofs: 8E7B5 -> hdlr Ofs: 8E7E7 -> mean Ofs: 8E7EF -> comappleiTunes Ofs: 8E803 -> name Ofs: 8E80B -> iTunSMPB Ofs: 8E817 -> data Ofs: 8E89B -> day Ofs: 8E8A3 -> data Ofs: 8E8CB -> too Ofs: 8E8D3 -> data Ofs: 8E8DF -> comappleVoiceMemos Ofs: 8E8F5 -> iPhone® OS711	Ofs: 14975 -> stbl Ofs: 1497C -> gstsd Ofs: 1497D -> stsd Ofs: 1498D -> mp4a Ofs: 149B1 -> esds Ofs: 149E4 -> stts Ofs: 149FC -> stsc Ofs: 14A18 -> stsz Ofs: 15140 -> stco Ofs: 1515C -> meta Ofs: 15168 -> hdlr Ofs: 1519A -> mean Ofs: 151A2 -> comappleiTunes Ofs: 151B6 -> name Ofs: 151BE -> iTunSMPB Ofs: 151CA -> data Ofs: 1524E -> day Ofs: 15256 -> data Ofs: 1527E -> too Ofs: 15286 -> data Ofs: 15292 -> comappleVoiceMemos Ofs: 152A8 -> iPhone® OS802	Ofs: 24FF3E -> stbl Ofs: 24FF45 -> gstsd Ofs: 24FF46 -> stsd Ofs: 24FF56 -> mp4a Ofs: 24FF7A -> esds Ofs: 24FFAD -> stts Ofs: 24FFC5 -> stsc Ofs: 24FFF9 -> stsz Ofs: 25CA4D -> stco Ofs: 25CA71 -> meta Ofs: 25CA7D -> hdlr Ofs: 25CAAF -> mean Ofs: 25CAB7 -> comappleiTunes Ofs: 25CACB -> name Ofs: 25CAD3 -> iTunSMPB Ofs: 25CADF -> data Ofs: 25CB63 -> day Ofs: 25CB6B -> data Ofs: 25CB93 -> too Ofs: 25CB9B -> data Ofs: 25CBA7 -> comappleVoiceMemos Ofs: 25CBBD -> iPhone® OS841	Ofs: 165B8 -> stbl Ofs: 165BF -> gstsd Ofs: 165C0 -> stsd Ofs: 165D0 -> mp4a Ofs: 165F4 -> esds Ofs: 16627 -> stts Ofs: 1663F -> stsc Ofs: 16667 -> stsz Ofs: 16E63 -> stco Ofs: 16EAB -> meta Ofs: 16EB7 -> hdlr Ofs: 16EE9 -> mean Ofs: 16EF1 -> comappleiTunes Ofs: 16F05 -> name Ofs: 16F0D -> iTunSMPB Ofs: 16F19 -> data Ofs: 16F9D -> day Ofs: 16FA5 -> data Ofs: 16FCD -> too Ofs: 16FD5 -> data Ofs: 16FE1 -> comappleVoiceMemos Ofs: 16FF6 -> iPhone® OS92	Ofs: 97515 -> stts Ofs: 97535 -> stsz Ofs: 9A5F1 -> stsc Ofs: 9A619 -> stco

Reference(s):

1. Grigoras C., Smith M.J. Forensic Analysis of Digital Audio File Structures and Formats, *Proceedings of the American Academy of Forensic Sciences*, 68th Annual Scientific Meeting, Las Vegas, NV. 2016.
2. Grigoras C., Rappaport D., Smith J. (2012) Analytical Framework for Digital Audio Authentication, AES 46th International Conference, Denver, USA.
3. Grigoras C., Smith J.M. (2013) Audio Enhancement and Authentication. In: Siegel JA and Saukko P.J. (eds.) *Encyclopedia of Forensic Sciences, Second Edition*. pp. 315-326. Waltham: Academic Press.
4. Koenig E.B., Lacey D.S., Reimond C.E. (2014) Selected Characteristics of MP3 Files Re-Encoded With Audio Editing Software, *Journal of Forensic Identification*. 64:3:304-321
5. Koenig E.B., Lacey D.S. (2014) Forensic Authenticity Analyses of the Header Data in Re-Encoded WMA Files From Small Olympus Audio Recorders. *Journal of the Audio Engineering Society*. 60:4:255-265

Forensic Audio, Metadata, Digital Evidence