Supplement 253

WAVEFORM COMPRESSION
DICOM WORKING GROUP 32
BEFORE PUBLIC COMMENT
2026-03-16

Current Situation

- DICOM does not yet support any Transfer Syntax for encapsulation of compressed Waveform data

- Neurophysiology recordings can become very large for different reasons:

- long recording time (e.g. epilepsy monitoring, sleep monitoring),

- using many electrodes and/or

- using a high sampling frequency for a better resolution

- Several codecs specifically designed for compression of biomedical data are developed by ITU

Long-term Monitoring (LTM) and Sleep Study IOD Use Cases:

1. Outpatient 6-Hour Video-EEG (VEEG) Study

2. Outpatient Ambulatory 72-hour EEG Study (No Video)

3. Outpatient Sleep Monitoring (Polysomnogram [PSG]) VEEG Study

4. Inpatient Long-Term Monitoring (LTM) 24-Hour Intensive Care Unit (ICU) Study

5. Inpatient Long-Term Monitoring (LTM) Presurgical Evaluation Epilepsy Monitoring Unit (EMU) 24-Hour Study

Use Case #1
Outpatient 6-Hour Video-EEG (VEEG) Study

Clinical Description:

This is a long recording in an outpatient neurophysiology lab which typically begins in the morning and extends into the afternoon.

Data Description:

Length of Recording: 6 hours
Discontinuities: none
Data Types Recorded:

- 19 EEG channels (Standard 10-20 surface EEG electrode placement)
- 1 ECG channel
- 2 EOG channels
- 2 EMG channels
- Multiplexed audio-video recording (MP4, 1080p Full HD)

Waveform Sampling Rate: 512 Hz
Waveform Bit Depth: 16
Estimated Data Size (for one study):

- Waveforms: (6 hr)(60 min/hr)(60 sec/min)(24 channels)(512 samples/sec)(2 bytes/sample) = ~ 500 MB
- Video: (6 hr)(3 GB/hr) = ~ 18 GB

Use Case #2
Outpatient Ambulatory 72-hour EEG Study (No Video)

Clinical Description: The patient has an appointment in the neurophysiology laboratory on Monday morning to be connected to monitoring and then returns to the neurophysiology laboratory on Thursday morning to be disconnected. The recording unit must be charged at home by the patient every 24 hours. The patient forgets to plug the recording unit into the charger on Tuesday but plugs it in on Wednesday morning. The recording system fails to record waveforms from 12:00 PM (noon) on Tuesday until 10:00 AM on Wednesday. The patient plugs the recording unit in to charge on Thursday night and attends the appointment in the neurophysiology lab to have EEG electrodes removed (and return the recording device) on Thursday morning.

Use Case #2
Outpatient Ambulatory 72-hour EEG Study (No Video)

Data Description:

Length of Recording: 50 hrs (10:00 AM on Monday to 12:00 PM on Tuesday; 10:00 AM on Wednesday to 10:00 AM on Thursday = 26 hr + 24 hr = 50 hr)

Discontinuities: one discontinuity between 12:00 PM on Tuesday to 10:00 AM on Wednesday

Channels Recorded:

- 19 EEG channels (Standard 10-20 surface EEG electrode placement)
- one ECG channel

Waveform Sampling Rate: 512 Hr

Waveform Bit Depth: 16 bits

Estimated Data Size (for one study):

Waveform: (50 hr)(60 min/hr)(60 sec/min)(20 channels)(512 samples/sec)(2 bytes/sample) = ~ 400 MB

Use Case #3
Outpatient Sleep Monitoring (Polysomnogram) VEEG Study

Clinical Description: This is an overnight sleep study performed in a Clinical Sleep Laboratory. This is considered an outpatient study because the patient is not admitted to the hospital for the study, although the patient lies in a bed in the Sleep Lab overnight for the recording. The patient typically arrives at the Sleep Lab at around 7:30 PM, the recording begins around 8:00-9:00 PM and the recording ends before 6:00 AM.

Use Case #3
Outpatient Sleep Monitoring (Polysomnogram) VEEG Study

Data Description:

Length of Recording: ~ 4-8 hours

Discontinuities: none

Data Types Recorded:

- 8 EEG channels (at positions C3, C4, F3, F4, O1, O2, M1, M2)
- 1 ECG channel
- 2 EOG channels
- 1 chin EMG channel
- 2 extremity (leg) EMG channels
- 5 respiratory waveform channels including thermistor, nasal flow, chest plethysmogram, 2 abdominal plethysmogram (Modality: RESP waveform)
- 1 PPG (pulse-ox) channel (Modality: hemodynamic [HD] waveform)
- 1 body position channel (Modality: POS waveform)
- 1 audio (only) channel (snore detector; will be encoded using one of DICOM audio IODs)
- Multiplexed audio-video recording (MP4, 720p)

Use Case #3
Outpatient Sleep Monitoring (Polysomnogram) VEEG Study

Data Description (continued):

Waveform Sampling Rate: 512 Hz

Waveform Bit Depth: 16

Estimated Data Size (for one study):

- Waveform: (8 hr)(60 min/hr)(60 sec/min)(20 channels)(512 samples/sec)(2 bytes/sample) = ~ 600 MB
- Audio (snore channel): (8 hr)(60 min/hr)(60 sec/min)(1 channel)(24,000 bits/sec)(1 byte/8 bits) = ~ 100 MB
- Video: (8 hr)(2 GB/hr) = ~ 18 GB

Use Case #4: Inpatient Long-Term Monitoring (LTM)
24-Hour Intensive Care Unit (ICU) VEEG Study

Clinical Description:

- This is an inpatient EEG recording made on a patient in the ICU. Typically, in the US, studies of approximately 24 hours are done sequentially from 1-14 days, depending on the clinical scenario. Monitoring for longer than an average of around 10 days substantially increases the risk of skin breakdown from the EEG surface electrodes.
- Individual studies are usually limited to 24 hours because (1) in case there is data corruption of a study, only 24 hours of recording will be lost and (2) because EEG technologists always will visit each patients receiving monitoring once in the morning to check the integrity of the recording equipment and electrode contacts, so it is a convenient time for the technologist to stop the study and start a new study.
- This patient had acute altered mental status, and the recording was paused between 10:00 AM and 12:00 noon while the patient was taken to have an MRI brain scan and then returned to their room in the ICU.

Use Case #4: Inpatient Long-Term Monitoring (LTM)
24-Hour Intensive Care Unit (ICU) VEEG Study

Data Description:

Length of Recording: 24 hr

Discontinuities: one discontinuity (no waveform recording between 10:00 AM and 12:00 PM)

Channels Recorded:

- 19 EEG channels (Standard 10-20 surface EEG electrode placement)
- 1 ECG channel
- 2 EOG channels
- Multiplexed audio-video recording (MP4, 1080p Full HD)

Waveform Sampling Rate: 512 Hr

Waveform Bit Depth: 16 bits

Estimated Data Size (for one study):

- Waveform: (6 hr)(60 min/hr)(60 sec/min)(24 channels)(512 samples/sec)(2 bytes/sample) = ~ 500 MB
- Video: (8 hr)(2 GB/hr) = ~16 GB

Use Case #5:   Inpatient Long-Term Monitoring (LTM) Presurgical Evaluation 24-Hr EMU VEEG Study

Clinical Description:

- This is an inpatient EEG recording made on a patient in the Epilepsy Monitoring Unit (EMU). Typically, in the US, studies of this type are limited to approximately 24 hours and are performed sequentially during the 2–7 day elective inpatient hospital admission.

- Studies are limited to 24 hours because (1) in case there is data corruption of a study, only 24 hours of recording will be lost and (2) because EEG technologists always will visit each patients receiving monitoring once in the morning to check the integrity of the recording equipment and electrode contacts, so it is a convenient time for the technologist to stop the study and start a new study.

Use Case #5: Inpatient Long-Term Monitoring (LTM) Presurgical Evaluation 24-Hr EMU VEEG Study

Data Description:

   Length of Recording: 24 hours

   Discontinuities: none

   Data Types Recorded:

- 25 EEG channels (IFCN 25 surface electrode montage)
- 1 ECG channel
- 2 EOG channels
- 4 EMG channels
- 1 PPG channel
- 2 Multiplexed audio-video recordings (MP4, 1080p Full HD) from two cameras on the ceiling of the patient's EMU monitoring room.

Use Case #5: Inpatient Long-Term Monitoring (LTM) Presurgical Evaluation 24-Hr EMU VEEG Study

Data Description:

Waveform Sampling Rate: 1000 Hz
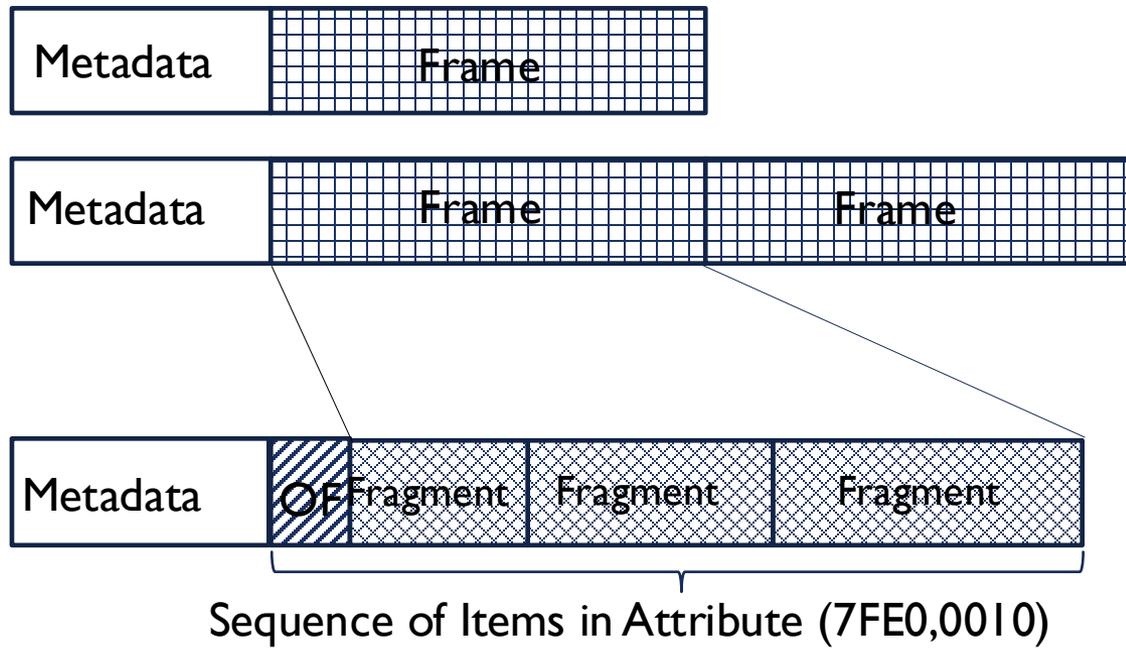
Waveform Bit Depth: 24

Estimated Data Size (for one study):

- Waveform: (24 hr)(60 min/hr)(60 sec/min)(32 channels)(1024 samples/sec)(3 bytes/sample) = ~ 8.5 GB
- Video: (24 hr)(3 GB/hr)(2 video cameras) = ~ 150 GB

Proposed change in this supplement:
add support for Waveform compression

- A codec specialized for compression/decompression of biomedical waveform data is developed by ITU – Telecommunications Standardization Sector / Video Coding Experts Group (VCEG) : **T.261**

- T.261 allows lossless, near lossless and lossy compression

- This supplement proposes:

  - An encapsulation mechanism for DICOM Waveforms to encapsulate compressed data

  - In analogy to existing image compression / encapsulation of compressed pixel data

  - At least one new Transfer Syntax for lossless compressed DICOM waveforms

Current Image Encoding: Native vs. Encapsulated

| Metadata | Frame |

| Metadata | Frame | Frame |

| Metadata | OF Fragment | Fragment | Fragment |

Sequence of Items in Attribute (7FE0,0010)

- The encoded stream of a single Frame may span multiple fragments.
- The Offset Table (OF) provides byte offsets to the start of the first Fragment for each Frame.

Current Image Encoding: Native vs. Encapsulated

Sequence of Items in Attribute (7FE0,0010)

Extended Offset Table in (7FE0,0001)

Sequence of Items in Attribute (7FE0,0010)

- Standard encoding: encoded pixel data are organized in a Sequence of Items, each with defined length, first Item in sequence is an offset table (OT).
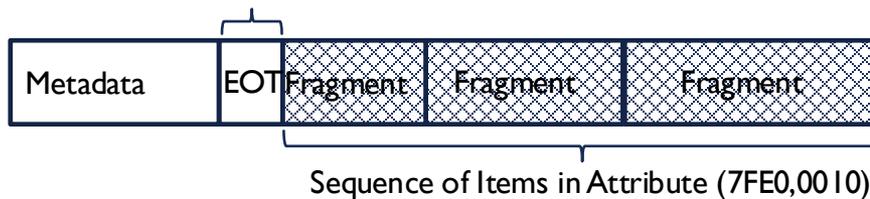
- Under some circumstances this OT might be replaced by a separate attribute – the extended offset table (EOT)
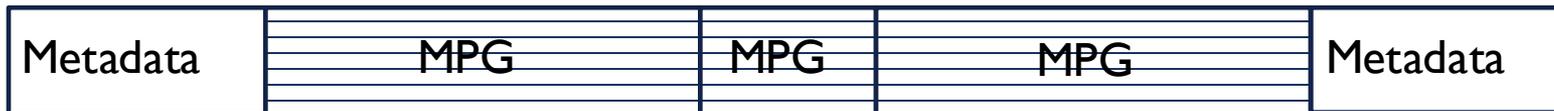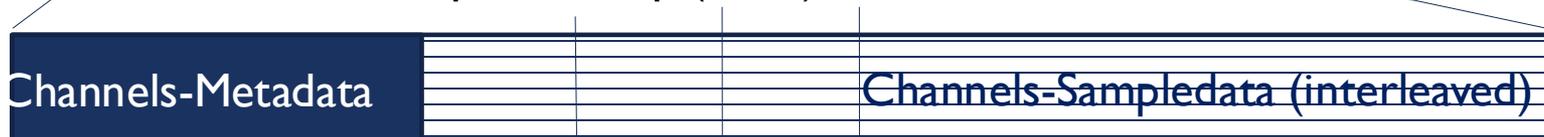
Current Waveform Encoding

Metadata	MPG	Metadata

Metadata	MPG	MPG	MPG	Metadata

within a Multiplex Group (MPG):

Channels-Metadata	Channels-Sampledata (interleaved)

C1S1, C2S1,C3S1, …CnS1,C1S2, C2S2, C3S2, …. CnSm

Encapsulation for Waveforms in Principle

Codec aspects

- The codec uses parts of a set of channels and encodes them to so called "chunks" (called "frames" in the ITU/VCEG spec.)

- The codec supports different „modes" – resulting in independant „chunks" (iframes) or dependant „chunks" (pframes)
  → only the first can be decompressed (and displayed) individually
  → the second ones can only be decompressed (and displayed) after at least one preceding independent frame and all preceding dependent chunks have been decompressed

- The Waveform Offset Table shall contain pointers to the independent "chunks" and optional timing information

Codec aspects – input parameters

- A broad range of parameters is supported by the codec, only a subset is required for lossless encoding

- **Input Parameter: channel groups**
  Channels may be grouped to so called "channel groups" which are encoded and decoded individually.

- default case: „joint channels": all channels of a DICOM Waveform Multiplex Group go into a single channel group (codec cfg param: ChannelGroupSize)

- ~~„individual channels": each channel of a DICOM Waveform Multiplex Group goes into a separate channel group~~

- **Input Parameter: „chunk" size**
  size of waveform blocks in seconds
  (this is always even length if Waveform Bits Allocated >= 16 and/or Sampling Frequency is a multiple of 2).

Codec aspects – not used in DICOM

- T.261 allows to store auxiliary metadata in the encoded bitstream: e.g. waveform type (EEG, EMG, ...)

- T.261 allows to store information about waveform features in the bitstream: indicates, that a portion of the waveform data has special characteristics or is of special interest

- T.261 allows to store annotations in the encoded bitstream

- T.261 supports security features:

- provide user identification information

- provide user authentication information

- provide authentication signature information

To discuss

- Sample Values embedded in Metadata?
  <mark>Is this problematic for rapid access to data? Should this be changed?</mark>

- A chosen encoding (Transfer Syntax) applies to all Multiplex Groups.
  <mark>Limitation to Waveforms with just a single Multiplex Group?</mark>

- Encapsulation mechanism?

  - Encapsulation in analogy to compressed multiframe images (OT contains pointers to decompress individual frames)?

  - Encapsulation in analogy to video codecs: no OT, encapsulation of whole video bitstream

- If first approach: there is a single Waveform Offset Table (OT) for each encoded MPG.

Ways to encode the OT

- 32-bit pointer – as it is done in imaging

- 64-bit pointer - if this is done in every case the OT becomes unnecessarily large for recordings < 4 GB
    - Use a different Transfer Syntax for such objects
    - Use a different Data Element for the encapsulated data

- Integration of Timestamps
    - Use the timestamps in the encoded chunks - ? Are they accessible via API?
    - Using an EOT and store the information there: will need a 64-bit word (OV) like the offsets and lengths per chunk → might result in very large meta data

DICOM aspects

- Discussed in WG-32 / 2025-11-20: Should the codec metadata only be embedded in the encoded result or in the DICOM metadata set: <mark>WG-32 was in favor for the second option (both).</mark>

- Check with WG-06:
  Long Term Monitoring (LTM) is - from a technical perspective - very similar to Routine Scalp EEG: how to extend the scope: introduce a new IOD for LTM or rename the existing IOD?
  <mark>New IOD – existing Work Item 2018-09-D (Neurophysiology Waveforms) seems sufficient</mark>