Network Working Group
Internet-Draft
Intended status: Informational
Expires: January 10, 2013

J. Spittka
K. Vos
Skype Technologies S.A.
JM. Valin
Mozilla

July 9, 2012

RTP Payload Format for Opus Speech and Audio Codec
draft-spittka-payload-rtp-opus-01.txt

Abstract

This document defines the Real-time Transport Protocol (RTP) payload format for packetization of Opus encoded speech and audio data that is essential to integrate the codec in the most compatible way. Further, media type registrations are described for the RTP payload format.

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction

The Opus codec is a speech and audio codec developed within the IETF Internet Wideband Audio Codec working group [codec]. The codec has a very low algorithmic delay and is is highly scalable in terms of audio bandwidth, bitrate, and complexity. Further, it provides different modes to efficiently encode speech signals as well as music signals, thus, making it the codec of choice for various applications using the Internet or similar networks.

This document defines the Real-time Transport Protocol (RTP) [RFC3550] payload format for packetization of Opus encoded speech and audio data that is essential to integrate the Opus codec in the most compatible way. Further, media type registrations are described for the RTP payload format. More information on the Opus codec can be obtained from the following IETF draft [Opus].

2. Conventions, Definitions and Acronyms used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

CPU: Central Processing Unit
IP: Internet Protocol
PSTN: Public Switched Telephone Network
samples: Speech or audio samples
SDP: Session Description Protocol

2.1. Audio Bandwidth

Throughout this document, we refer to the following definitions:

Abbreviation	Name	Bandwidth	Sampling
nb	Narrowband	0 - 4000	8000
mb	Mediumband	0 - 6000	12000
wb	Wideband	0 - 8000	16000
swb	Super-wideband	0 - 12000	24000
fb	Fullband	0 - 20000	48000

Audio bandwidth naming

Table 1

3. Opus Codec

The Opus [Opus] speech and audio codec has been developed to encode speech signals as well as audio signals. Two different modes, a voice mode or an audio mode, may be chosen to allow the most efficient coding dependent on the type of input signal, the sampling frequency of the input signal, and the specific application.

The voice mode allows to efficiently encode voice signals at lower bit rates while the audio mode is optimized for audio signals at medium and higher bitrates.

The Opus speech and audio codec is highly scalable in terms of audio bandwidth and bitrate and complexity. Further, Opus allows to transmit stereo signals.

3.1. Network Bandwidth

Opus supports all bitrates from 6 kb/s to 510 kb/s. The bitrate can be changed dynamically within that range. All other parameters being equal, higher bitrate results in higher quality.

3.1.1. Recommended Bitrate

For a frame size of 20 ms, these are the bitrate "sweet spots" for Opus in various configurations:

- o 8-12 kb/s for NB speech,
- o 16-20 kb/s for WB speech,
- o 28-40 kb/s for FB speech,
- o 48-64 kb/s for FB mono music, and
- o 64-128 kb/s for FB stereo music.

3.1.2. Variable versus Constant Bit Rate

For the same average bitrate, variable bitrate (VBR) can achieve higher quality than constant bitrate (CBR). For the majority of voice transmission application, VBR is the best choice. One potential reason for choosing CBR is the potential information leak that _may_ occur when encrypting the compressed stream. See [RFC6562] for guidelines on when VBR is appropriate for encrypted audio communications. In the case where an existing VBR stream needs to be converted to CBR for security reasons, then the Opus padding mechanism described in [Opus] is the RECOMMENDED way to achieve padding because the RTP padding bit is unencrypted.

The bitrate can be adjusted at any point in time. To avoid congestion, the average bitrate SHOULD be adjusted to the available network capacity. If no target bitrate is specified the average

bitrate may go up to the highest bitrate specified in Section 3.1.1.

3.1.3. Discontinuous Transmission (DTX)

The Opus codec may, as described in Section 3.1.2, be operated with an adaptive bitrate. In that case, the bitrate will automatically be reduced for certain input signals like periods of silence. During continuous transmission the bitrate will be reduced, when the input signal allows to do so, but the transmission to the receiver itself will never be interrupted. Therefore, the received signal will maintain the same high level of quality over the full duration of a transmission while minimizing the average bit rate over time.

In cases where the bitrate of Opus needs to be reduced even further or in cases where only constant bitrate is available, the Opus encoder may be set to use discontinuous transmission (DTX), where parts of the encoded signal that correspond to periods of silence in the input speech or audio signal are not transmitted to the receiver.

On the receiving side, the non-transmitted parts will be handled by a frame loss concealment unit in the Opus decoder which generates a comfort noise signal to replace the non transmitted parts of the speech or audio signal.

The DTX mode of Opus will have a slightly lower speech or audio quality than the continuous mode. Therefore, it is RECOMMENDED to use Opus in the continuous mode unless restraints on network capacity are severe. The DTX mode can be engaged for operation in both adaptive or constant bitrate.

3.2. Complexity

Complexity can be scaled to optimize for CPU resources in real-time, mostly as a trade-off between audio quality and bitrate. Also, different modes of Opus have different complexity.

3.3. Forward Error Correction (FEC)

The voice mode of Opus allows for "in-band" forward error correction (FEC) data to be embedded into the bit stream of Opus. This FEC scheme adds redundant information about the previous packet (n-1) to the current output packet n. For each frame, the encoder decides whether to use FEC based on (1) an externally-provided estimate of the channel's packet loss rate; (2) an externally-provided estimate of the channel's capacity; (3) the sensitivity of the audio or speech signal to packet loss; (4) whether the receiving decoder has indicated it can take advantage of "in-band" FEC information. The decision to send "in-band" FEC information is entirely controlled by

the encoder and therefore no special precautions for the payload have to be taken.

On the receiving side, the decoder can take advantage of this additional information when, in case of a packet loss, the next packet is available. In order to use the FEC data, the jitter buffer needs to provide access to payloads with the FEC data. The decoder API function has a flag to indicate that a FEC frame rather than a regular frame should be decoded. If no FEC data is available for the current frame, the decoder will consider the frame lost and invokes the frame loss concealment.

If the FEC scheme is not implemented on the receiving side, FEC SHOULD NOT be used, as it leads to an inefficient usage of network resources. Decoder support for FEC SHOULD be indicated at the time a session is set up.

3.4. Stereo Operation

Opus allows for transmission of stereo audio signals. This operation is signaled in-band in the Opus payload and no special arrangement is required in the payload format. Any implementation of the Opus decoder MUST be capable of receiving stereo signals.

If a decoder can not take advantage of the benefits of a stereo signal this SHOULD be indicated at the time a session is set up. In that case the sending side SHOULD NOT send stereo signals as it leads to an inefficient usage of the network.

4. Opus RTP Payload Format

The payload format for Opus consists of the RTP header and Opus payload data.

4.1. RTP Header Usage

The format of the RTP header is specified in [RFC3550]. The Opus payload format uses the fields of the RTP header consistent with this specification.

The payload length of Opus is a multiple number of octets and therefore no padding is required. The payload MAY be padded by an integer number of octets according to [RFC3550].

The marker bit (M) of the RTP header has no function in combination with Opus and MAY be ignored.

The RTP payload type for Opus has not been assigned statically and is expected to be assigned dynamically.

The receiving side MUST be prepared to receive duplicates of RTP packets. Only one of those payloads MUST be provided to the Opus decoder for decoding and others MUST be discarded.

Opus supports 5 different audio bandwidths which may be adjusted during the duration of a call. The RTP timestamp clock frequency is defined as the highest supported sampling frequency of Opus, i.e. 48000 Hz, for all modes and sampling rates of Opus. The unit for the timestamp is samples per single (mono) channel. The RTP timestamp corresponds to the sample time of the first encoded sample in the encoded frame. For sampling rates lower than 48000 Hz the number of samples has to be multiplied with a multiplier according to Table 2 to determine the RTP timestamp.

fs (Hz)	Multiplier
8000	6
12000	4
16000	3
24000	2
48000	1

fs specifies the audio sampling frequency in Hertz (Hz); Multiplier is the value that the number of samples have to be multiplied with to calculate the RTP timestamp.

Table 2

4.2. Payload Structure

The Opus encoder can be set to output encoded frames representing 2.5, 5, 10, 20, 40, or 60 ms of speech or audio data. Further, an arbitrary number of frames can be combined into a packet. The maximum packet length is limited to the amount of encoded data representing 120 ms of speech or audio data. The packetization of encoded data is purely done by the Opus encoder and therefore only one packet output from the Opus encoder MUST be used as a payload.

Figure 1 shows the structure combined with the RTP header.

```
+----------+--------------+
|RTP Header| Opus Payload |
+----------+--------------+
```

Figure 1: Payload Structure with RTP header

Table 3 shows supported frame sizes for different modes and sampling rates of Opus and how the timestamp needs to be incremented for packetization.

Mode	fs	2.5	5	10	20	40	60
ts incr	all	120	240	480	960	1920	2880
voice	nb/mb/wb/swb/fb			x	x	x	x
audio	nb/wb/swb/fb	x	x	x	x		

Mode specifies the Opus mode of operation; fs specifies the audio sampling frequency in Hertz (Hz); 2.5, 5, 10, 20, 40, and 60 represent the duration of encoded speech or audio data in a packet; ts incr specifies the value the timestamp needs to be incremented for the representing packet size. For multiple frames in a packet these values have to be multiplied with the respective number of frames.

Table 3

5. Congestion Control

The adaptive nature of the Opus codec allows for an efficient congestion control.

The target bitrate of Opus can be adjusted at any point in time and thus allowing for an efficient congestion control. Furthermore, the amount of encoded speech or audio data encoded in a single packet can be used for congestion control since the transmission rate is inversely proportional to these frame sizes. A lower packet transmission rate reduces the amount of header overhead but at the same time increases latency and error sensitivity and should be done with care.

It is RECOMMENDED that congestion control is applied during the transmission of Opus encoded data.

6. IANA Considerations

One media subtype (audio/opus) has been defined and registered as described in the following section.

6.1. Opus Media Type Registration

Media type registration is done according to [RFC4288] and [RFC4855].

Type name: audio

Subtype name: opus

Required parameters:

rate: RTP timestamp clock rate is incremented with 48000 Hz clock rate for all modes of Opus and all sampling frequencies. For audio sampling rates other than 48000 Hz the rate has to be adjusted to 48000 Hz according to Table 2.

Optional parameters:

maxcodedaudiobandwidth: a hint about the maximum audio bandwidth that the receiver is capable of rendering. The decoder MUST be capable of decoding any audio bandwidth but due to hardware limitations only signals up to the specified audio bandwidth can be processed. Sending signals with higher audio bandwidth results in higher than necessary network usage and encoding complexity, so an encoder SHOULD NOT encode frequencies above the audio bandwidth specified by maxcodedaudiobandwidth. Possible values are nb, mb, wb, swb, fb. By default, the receiver is assumed to have no limitations, i.e. fb.

maxptime: the decoder's maximum length of time in milliseconds rounded up to the next full integer value represented by the media in a packet that can be encapsulated in a received packet according to Section 6 of [RFC4566]. Possible values are 3, 5, 10, 20, 40, and 60 or an arbitrary multiple of Opus frame sizes rounded up to the next full integer value up to a maximum value of 120 as defined in Section 4. If no value is specified, 120 is assumed as default. This value is a recommendation by the decoding side to ensure the best performance for the decoder. The decoder MUST be capable of accepting any allowed packet sizes to ensure maximum compatibility.

ptime: the decoder's recommended length of time in milliseconds rounded up to the next full integer value represented by the media in a packet according to Section 6 of [RFC4566]. Possible values are 3, 5, 10, 20, 40, or 60 or an arbitrary multiple of Opus frame sizes rounded up to the next full integer value up to a maximum value of 120 as defined in Section 4. If no value is specified, 20 is assumed as default. If ptime is greater than maxptime, ptime MUST be ignored. This parameter MAY be changed during a session. This value is a recommendation by the decoding side to ensure the best performance for the decoder. The decoder MUST be capable of accepting any allowed packet sizes to ensure maximum compatibility.

minptime: the decoder's minimum length of time in milliseconds rounded up to the next full integer value represented by the media in a packet that SHOULD be encapsulated in a received packet according to Section 6 of [RFC4566]. Possible values are 3, 5, 10, 20, 40, and 60 or an arbitrary multiple of Opus frame sizes rounded up to the next full integer value up to a maximum value of 120 as defined in Section 4. If no value is specified, 3 is assumed as default. This value is a recommendation by the decoding side to ensure the best performance for the decoder. The decoder MUST be capable to accept any allowed packet sizes to ensure maximum compatibility.

maxaveragebitrate: specifies the maximum average receive bitrate of a session in bits per second (b/s). The actual value of the bitrate may vary as it is dependent on the characteristics of the media in a packet. Note that the maximum average bitrate MAY be modified dynamically during a session. Any positive integer is allowed but values outside the range between 6000 and 510000 SHOULD be ignored. If no value is specified, the maximum value specified in Section 3.1.1 for the corresponding mode of Opus and corresponding maxcodedaudiobandwidth: will be the default.

stereo: specifies whether the decoder prefers receiving stereo or mono signals. Possible values are 1 and 0 where 1 specifies that stereo signals are preferred and 0 specifies that only mono signals are preferred. Independent of the stereo parameter every receiver MUST be able to receive and decode stereo signals but sending stereo signals to a receiver that signaled a preference for mono signals may result in higher than necessary network utilisation and encoding complexity. If no value is specified, mono is assumed (stereo=0).

cbr: specifies if the decoder prefers the use of a constant bitrate versus variable bitrate. Possible values are 1 and 0 where 1 specifies constant bitrate and 0 specifies variable bitrate. If no value is specified, cbr is assumed to be 0. Note that the maximum average bitrate may still be changed, e.g. to adapt to changing network conditions.

useinbandfec: specifies that Opus in-band FEC is supported by the decoder and MAY be used during a session. Possible values are 1 and 0. It is RECOMMENDED to provide 0 in case FEC is not implemented on the receiving side. If no value is specified, useinbandfec is assumed to be 1.

usedtx: specifies if the decoder prefers the use of DTX. Possible values are 1 and 0. If no value is specified, usedtx is assumed to be 0.

Encoding considerations:

Opus media type is framed and consists of binary data according to Section 4.8 in [RFC4288].

Security considerations:

See Section 7 of this document.

Interoperability considerations: none

Published specification: none

Applications that use this media type:

Any application that requires the transport of speech or audio data may use this media type. Some examples are, but not limited to, audio and video conferencing, Voice over IP, media streaming.

Person & email address to contact for further information:

SILK Support silksupport@skype.net
Jean-Marc Valin jmvalin@jmvalin.ca

Intended usage: COMMON

Restrictions on usage:

For transfer over RTP, the RTP payload format (Section 4 of this document) SHALL be used.

Author:

Julian Spittka julian.spittka@skype.net

Koen Vos koen.vos@skype.net

Jean-Marc Valin jmvalin@jmvalin.ca

Change controller: TBD

6.2. Mapping to SDP Parameters

The information described in the media type specification has a specific mapping to fields in the Session Description Protocol (SDP) [RFC4566], which is commonly used to describe RTP sessions. When SDP is used to specify sessions employing the Opus codec, the mapping is as follows:

- o The media type ("audio") goes in SDP "m=" as the media name.
- o The media subtype ("opus") goes in SDP "a=rtpmap" as the encoding name. The RTP clock rate in "a=rtpmap" MUST be mapped to the required media type parameter "rate".
- o The optional media type parameters "ptime" and "maxptime" are mapped to "a=ptime" and "a=maxptime" attributes, respectively, in the SDP.
- o All remaining media type parameters are mapped to the "a=fmtp" attribute in the SDP by copying them directly from the media type parameter string as a semicolon-separated list of parameter=value pairs (e.g. maxaveragebitrate=20000).

Below are some examples of SDP session descriptions for Opus:

Example 1: Standard session with 48000 Hz clock rate

```
m=audio 54312 RTP/AVP 101
a=rtpmap:101 opus/48000
```

Example 2: 16000 Hz clock rate, maximum packet size of 40 ms, recommended packet size of 40 ms, maximum average bitrate of 20000

bps, stereo signals are preferred, FEC is allowed, DTX is not allowed

```
m=audio 54312 RTP/AVP 101
a=rtpmap:101 opus/48000
a=fmtp:101 maxcodedaudiobandwidth=wb; maxaveragebitrate=20000;
stereo=1; useinbandfec=1; usedtx=0
a=ptime:40
a=maxptime:40
```

6.2.1. Offer-Answer Model Considerations for Opus

When using the offer-answer procedure described in [RFC3264] to negotiate the use of Opus, the following considerations apply:

- o Opus supports several clock rates. For signaling purposes only the highest, i.e. 48000, is used. The actual clock rate of the corresponding media is signaled inside the payload and is not subject to this payload format description. The decoder MUST be capable to decode every received clock rate. An example is shown below:

```
m=audio 54312 RTP/AVP 100
a=rtpmap:100 opus/48000
```

- o The parameters "ptime" and "maxptime" are unidirectional receive-only parameters and typically will not compromise interoperability; however, dependent on the set values of the parameters the performance of the application may suffer. [RFC3264] defines the SDP offer-answer handling of the "ptime" parameter. The "maxptime" parameter MUST be handled in the same way.
- o The parameter "minptime" is a unidirectional receive-only parameters and typically will not compromise interoperability; however, dependent on the set values of the parameter the performance of the application may suffer and should be set with care.
- o The parameter "maxcodedaudiobandwidth" is a unidirectional receive-only parameter that reflects limitations of the local receiver. The sender of the other side SHOULD NOT send with an audio bandwidth higher than "maxcodedaudiobandwidth" as this would lead to inefficient use of network resources. The "maxcodedaudiobandwidth" parameter does not affect interoperability. Also, this parameter SHOULD NOT be used to adjust the audio bandwidth as a function of the bitrates, as this

is the responsability of the Opus encoder implementation.

- o The parameter "maxaveragebitrate" is a unidirectional receive-only parameter that reflects limitations of the local receiver. The sender of the other side MUST NOT send with an average bitrate higher than "maxaveragebitrate" as it might overload the network and/or receiver. The parameter "maxaveragebitrate" typically will not compromise interoperability; however, dependent on the set value of the parameter the performance of the application may suffer and should be set with care.
- o If the parameter "maxaveragebitrate" is below the range specified in Section 3.1.1 the session MUST be rejected.
- o The parameter "stereo" is a unidirectional receive-only parameter.
- o The parameter "cbr" is a unidirectional receive-only parameter.
- o The parameter "useinbandfec" is a unidirectional receive-only parameter.
- o The parameter "usedtx" is a unidirectional receive-only parameter.
- o Any unknown parameter in an offer MUST be ignored by the receiver and MUST be removed from the answer.

6.2.2. Declarative SDP Considerations for Opus

For declarative use of SDP such as in Session Announcement Protocol (SAP), [RFC2974], and RTSP, [RFC2326], for Opus, the following needs to be considered:

- o The values for "maxptime", "ptime", "minptime", "maxcodedaudiobandwidth", and "maxaveragebitrate" should be selected carefully to ensure that a reasonable performance can be achieved for the participants of a session.
- o The values for "maxptime", "ptime", and "minptime" of the payload format configuration are recommendations by the decoding side to ensure the best performance for the decoder. The decoder MUST be capable to accept any allowed packet sizes to ensure maximum compatibility.
- o All other parameters of the payload format configuration are declarative and a participant MUST use the configurations that are provided for the session. More than one configuration may be provided if necessary by declaring multiple RTP payload types; however, the number of types should be kept small.

7. Security Considerations

All RTP packets using the payload format defined in this specification are subject to the general security considerations discussed in the RTP specification [RFC3550] and any profile from e.g. [RFC3711] or [RFC3551].

This payload format transports Opus encoded speech or audio data, hence, security issues include confidentiality, integrity protection, and authentication of the speech or audio itself. The Opus payload format does not have any built-in security mechanisms. Any suitable external mechanisms, such as SRTP [RFC3711], MAY be used.

This payload format and the Opus encoding do not exhibit any significant non-uniformity in the receiver-end computational load and thus are unlikely to pose a denial-of-service threat due to the receipt of pathological datagrams.

8. Acknowledgements

TBD

9. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2326] Schulzrinne, H., Rao, A., and R. Lanphier, "Real Time Streaming Protocol (RTSP)", RFC 2326, April 1998.

[RFC2974] Handley, M., Perkins, C., and E. Whelan, "Session Announcement Protocol", RFC 2974, October 2000.

[RFC3264] Rosenberg, J. and H. Schulzrinne, "An Offer/Answer Model with Session Description Protocol (SDP)", RFC 3264, June 2002.

[RFC3550] Schulzrinne, H., Casner, S., Frederick, R., and V. Jacobson, "RTP: A Transport Protocol for Real-Time Applications", STD 64, RFC 3550, July 2003.

[RFC3551] Schulzrinne, H. and S. Casner, "RTP Profile for Audio and Video Conferences with Minimal Control", STD 65, RFC 3551, July 2003.

[RFC3711] Baugher, M., McGrew, D., Naslund, M., Carrara, E., and K. Norrman, "The Secure Real-time Transport Protocol (SRTP)", RFC 3711, March 2004.

[RFC4288] Freed, N. and J. Klensin, "Media Type Specifications and Registration Procedures", BCP 13, RFC 4288, December 2005.

[RFC4566] Handley, M., Jacobson, V., and C. Perkins, "SDP: Session Description Protocol", RFC 4566, July 2006.

[RFC4855] Casner, S., "Media Type Registration of RTP Payload Formats", RFC 4855, February 2007.

[RFC6562] Perkins, C. and JM. Valin, "Guidelines for the Use of Variable Bit Rate Audio with Secure RTP", RFC 6562, March 2012.

Appendix A. Informational References

[codec] http://datatracker.ietf.org/wg/codec/
[Opus] http://datatracker.ietf.org/doc/draft-ietf-codec-opus/

Authors' Addresses

Julian Spittka
Skype Technologies S.A.
3210 Porter Drive
Palo Alto, CA 94304
USA

Email: julian.spittka@skype.net

Koen Vos
Skype Technologies S.A.
3210 Porter Drive
Palo Alto, CA 94304
USA

Email: koen.vos@skype.net

Jean-Marc Valin
Mozilla
650 Castro Street
Mountain View, CA 94041
USA

Email: jmvalin@jmvalin.ca