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                A Session Initiation Protocol (SIP) usage for Trickle ICE
                      draft-ietf-mmusic-trickle-ice-sip-07

Abstract

   The Interactive Connectivity Establishment (ICE) protocol describes a
   Network Address Translator (NAT) traversal mechanism for UDP-based
   multimedia sessions established with the Offer/Answer model. The ICE
   extension for Incremental Provisioning of Candidates (Trickle ICE)
   defines a mechanism that allows ICE agents to shorten session
   establishment delays by making the candidate gathering and
   connectivity checking phases of ICE non-blocking and by executing
   them in parallel.

   This document defines usage semantics for Trickle ICE with the
   Session Initiation Protocol (SIP).

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1. Introduction

   The Interactive Connectivity Establishment protocol
   [I-D.ietf-mmusic-rfc5245bis] describes a mechanism for NAT traversal
   that consists of three main phases: a phase where an agent gathers a
   set of candidate transport addresses (source IP address, port and
   transport protocol), a second phase where these candidates are sent
   to a remote agent and this gathering procedure is repeated and,
   finally, a third phase where connectivity between all candidates in
   both sets is checked (connectivity checks). Once these phases have
   been completed, and only then, can both agents begin communication.
   According to [I-D.ietf-mmusic-rfc5245bis] the three phases above
   happen consecutively, in a blocking way, which can introduce
   undesirable latency during session establishment.

   The Trickle ICE extension [I-D.ietf-ice-trickle] defines generic
   semantics required for these ICE phases to happen simultaneously, in
   a non-blocking way and hence speed up session establishment.

   This specification defines a usage of Trickle ICE with the Session
   Initiation Protocol (SIP)[RFC3261]. It describes how ICE candidates
   are to be incrementally exchanged with SIP INFO requests and how the
   Half Trickle and Full Trickle modes defined in [I-D.ietf-ice-trickle]
   are to be used by SIP User Agents (UAs) depending on their
   expectations for support of Trickle ICE by a remote agent.

   This document defines a new Info Package as specified in [RFC6086]
   for use with Trickle ICE.

2. Terminology

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].

This specification makes use of all terminology defined by the
protocol for Interactive Connectivity Establishment in
[I-D.ietf-mmusic-rfc5245bis] and its Trickle ICE extension
[I-D.ietf-ice-trickle]. It is assumed that the reader will be
familiar with the terminology from both documents.

3. Protocol Overview

Using ICE for SIP according to [I-D.ietf-mmusic-ice-sip-sdp] the ICE
candidates are exchanged solely using SDP Offer/Answer as per
[RFC3264]. This specification defines an additional mechanism where
candidates can be exchanged using SIP INFO messages and a newly
defined Info Package [RFC6086]. This allows ICE candidates to also
be sent in parallel to an ongoing Offer/Answer negotiation and/or
after the completion of the Offer/Answer negotiation.

Typically, in cases where Trickle ICE is fully supported, the Offerer
would send an INVITE request containing a subset of candidates. Once
an early dialog is established the Offerer can continue sending
candidates in INFO requests within that dialog.

Similarly, an Answerer can send ICE candidates using INFO messages
within the dialog established by its 18x provisional response.
Figure 1 shows such a sample exchange:

```
    STUN/Turn                                             STUN/TURN
     Servers              Alice                 Bob        Servers
        |                    |                    |            |
        |  STUN Bi.Req.  |    INVITE (Offer)     |            |
        |<--------------|---------------------->|            |
        |                    |     183 (Answer)      | TURN Alloc Req |
        | STUN Bi.Resp. |<----------------------|-------------->|
        |-------------->|  INFO/OK (SRFLX Cand.) |            |
        |                    |---------------------->| TURN Alloc Resp|
        |                    |  INFO/OK (Relay Cand.) |<--------------|
        |                    |<----------------------|            |
        |                    |                    |            |
        |                    | More Cands & ConnChecks|          |
        |                    |<=====================>|           |
        |                    |                    |            |
        |                    |        200 OK         |            |
        |                    |<----------------------|            |
        |                    |         ACK          |            |
        |                    |---------------------->|            |
        |                    |                    |            |
        |                    |   5245 SIP re-INVITE  |            |
        |                    |---------------------->|            |
        |                    |        200 OK         |            |
        |                    |<----------------------|            |
        |                    |         ACK          |            |
        |                    |---------------------->|            |
        |                    |                    |            |
        |                    |<===== MEDIA FLOWS =====>|          |
        |                    |                    |            |
```
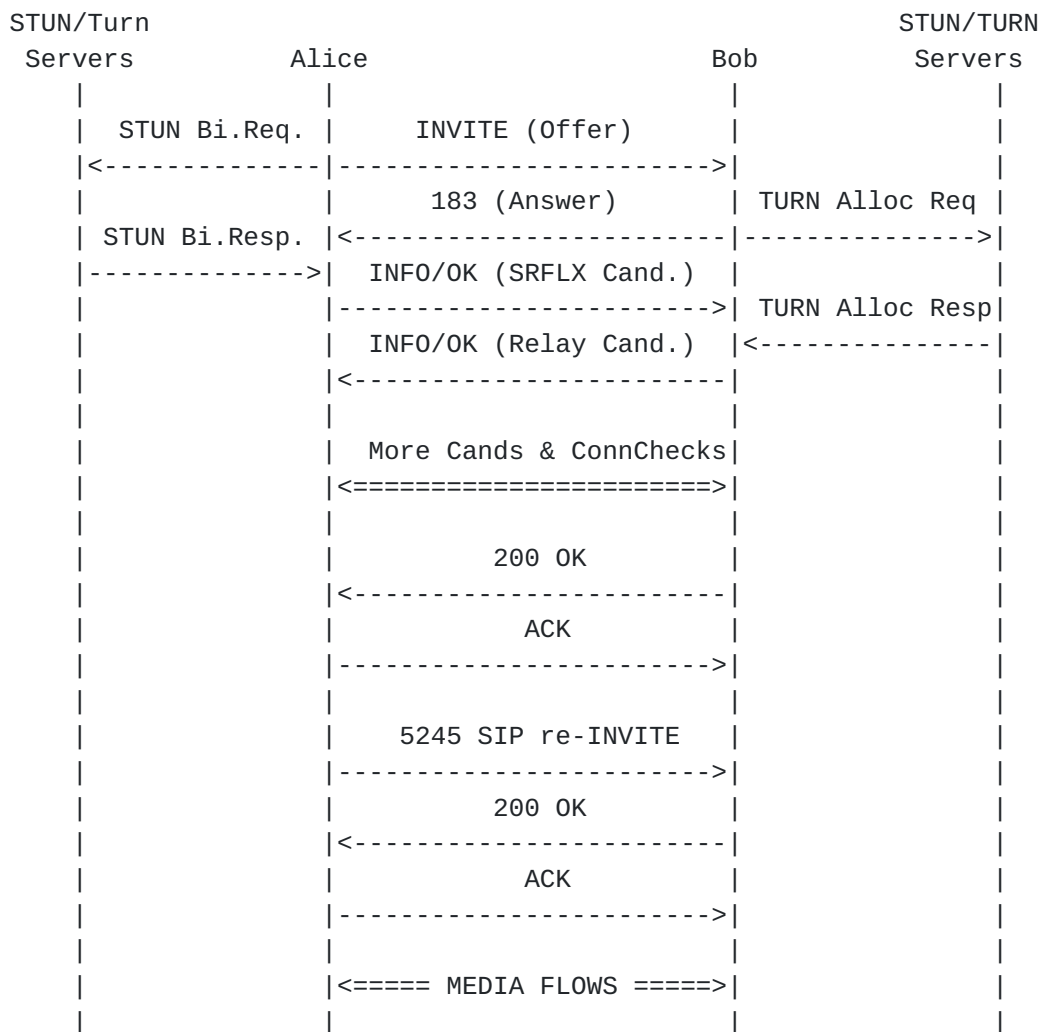
                 Figure 1: Sample Trickle ICE scenario with SIP

3.1. Discovery issues

   In order to benefit from Trickle ICE's full potential and reduce
   session establishment latency to a minimum, Trickle ICE agents need
   to generate SDP Offers and Answers that contain incomplete,
   potentially empty sets of candidates. Such Offers and Answers can
   only be handled meaningfully by agents that actually support
   incremental candidate provisioning, which implies the need to confirm
   such support before actually using it.

   Contrary to other protocols, like XMPP [RFC6120], where "in advance"
   capability discovery is widely implemented, the mechanisms that allow
   this for SIP (i.e., a combination of UA Capabilities [RFC3840] and
   GRUU [RFC5627]) have only seen low levels of adoption. This presents
   an issue for Trickle ICE implementations as SIP UAs do not have an

obvious means of verifying that their peer will support incremental
candidate provisioning.

The Half Trickle mode of operation defined in the Trickle ICE
specification [I-D.ietf-ice-trickle] provides one way around this, by
requiring the first Offer to contain a complete set of local ICE
candidates and only using incremental provisioning of remote
candidates for the rest of the session.

While using Half Trickle does provide a working solution it also
comes at the price of increased latency. Section 5 therefore makes
several alternative suggestions that enable SIP UAs to engage in Full
Trickle right from their first Offer: Section 5.1 discusses the use
of on-line provisioning as a means of allowing use of Trickle ICE for
all endpoints in controlled environments. Section 5.2 describes
anticipatory discovery for implementations that actually do support
GRUU and UA Capabilities and Section 5.4 discusses the implementation
and use of Half Trickle by SIP UAs where none of the above are an
option.

3.2. Relationship with the Offer/Answer Model

From the perspective of all SIP middle boxes and proxies, and with
the exception of the actual INFO messages, signaling in general and
Offer/Answer exchanges in particular would look the same way for
Trickle ICE as they would for ICE for SIP
[I-D.ietf-mmusic-ice-sip-sdp].

```
    +------------------------------+  +------------------------------+
    |   Alice      +--------------+ |  | +--------------+   Bob       |
    |              | Offer/Answer | |  | | Offer/Answer |             |
    | +-------+    |    Module    | |  | |    Module    |   +-------+ |
    | | ICE   |    +--------------+ |  | +--------------+   | ICE   | |
    | | Agent |          |         |  | |          |       | Agent | |
    | +-------+          |         |  | |          |       +-------+ |
    +------------------------------+  +------------------------------+
         |              |              |                  |
         |              |   INVITE (Offer)  |             |
         |              |-------------------->|           |
         |              |    183 (Answer)   |             |
         |              |<-------------------|            |
         |              |              |                  |
         |                                                |
         |        SIP INFO (more candidates)              |
         |----------------------------------------------->|
         |        SIP INFO (more candidates)              |
         |<-----------------------------------------------|
         |                                                |
         |        STUN Binding Requests/Responses         |
         |----------------------------------------------->|
         |        STUN Binding Requests/Responses         |
         |<-----------------------------------------------|
         |                                                |
         |              |              |                  |
         |              |  5245 SIP re-INVITE |           |
         |              |-------------------->|           |
         |              |      200 OK       |             |
         |              |<-------------------|            |
```
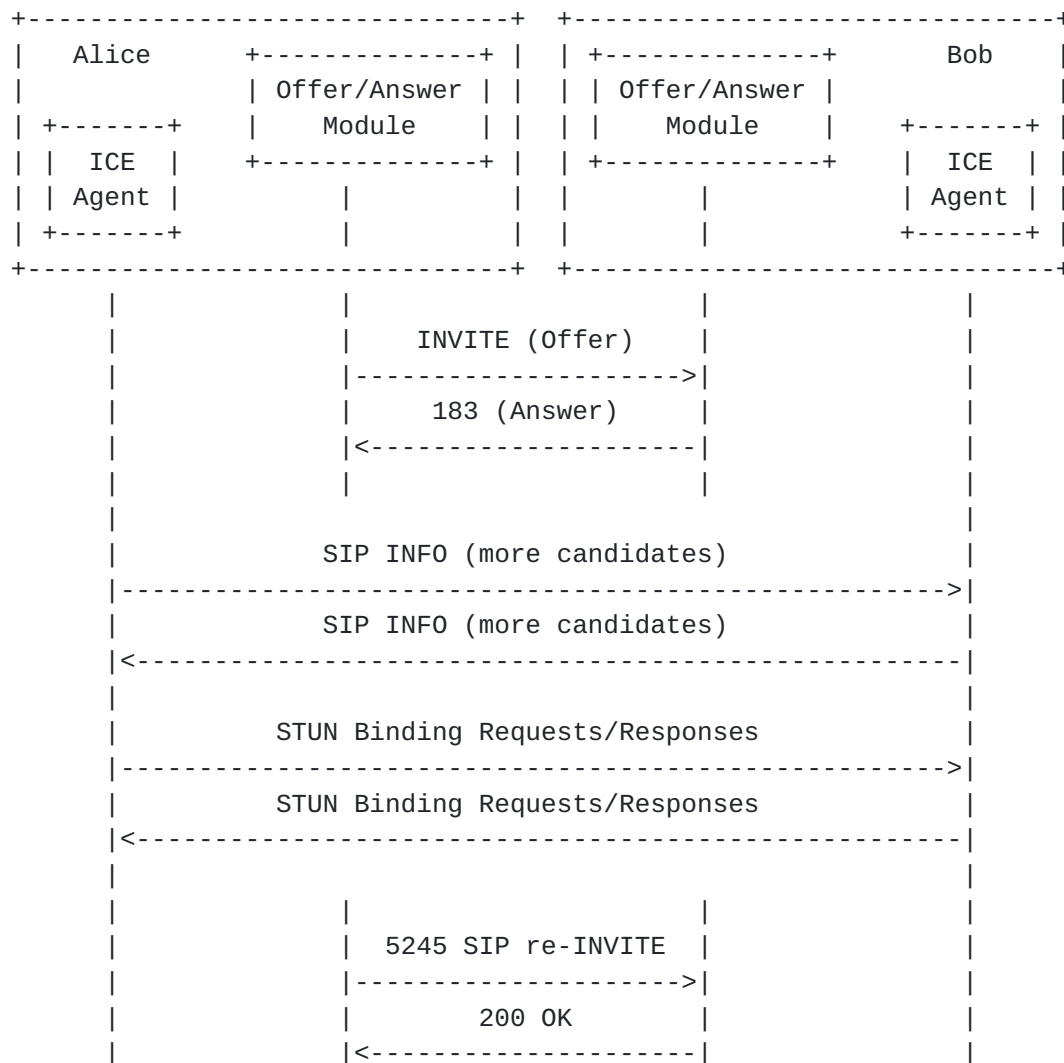
Figure 2: Distinguishing between Trickle ICE and traditional
signaling.

From an architectural viewpoint, as displayed on Figure 2, exchanging
candidates through SIP INFO requests could be represented as
signaling between ICE agents and not between Offer/Answer modules of
SIP User Agents. Then, such INFO requests do not impact the state of
the Offer/Answer transaction other than providing additional
candidates. Consequently, INFO requests are not considered Offers or
Answers. Nevertheless, candidates that have been exchanged using
INFO SHALL be included in subsequent Offers or Answers. The version
number in the "o=" line of that subsequent offer would need to be
incremented by 1 per the rules in [RFC3264].

4. Incremental Signaling of ICE candidates

   Trickle ICE agents will construct Offers and Answers with ICE
   descriptions compliant to [I-D.ietf-ice-trickle] and the following
   additional SIP-specific additions:

   1. Trickle ICE agents MUST indicate support for Trickle ICE by
       including the option-tag 'trickle-ice' in a SIP Supported: header
       field within all SIP INVITE requests and responses.

   2. Trickle ICE agents MAY exchange additional ICE candidates using
       INFO requests within an existing INVITE dialog usage (including
       an early dialog) as specified in [RFC6086]. The INFO messages
       carry an Info-Package: trickle-ice. Trickle ICE agents MUST be
       prepared to receive INFO requests within that same dialog usage,
       containing additional candidates or an indication for the end of
       such candidates

   3. Trickle ICE agents MAY exchange additional ICE candidates before
       the Answerer has sent the Answer provided that an invite dialog
       usage is established at both Trickle ICE agents. Note that in
       case of forking multiple early dialogs will exist.

   The following section provide further details on how Trickle ICE
   agents establish the INVITE dialog usage such that they can trickle
   candidates.

4.1. Establishing the dialog

   In order for SIP UAs to be able to start trickling, the following two
   conditions need to be satisfied:

   o Trickle ICE support at the peer agent MUST be confirmed.

   o The dialog at both peers MUST be in early or confirmed state.

   Section 5 discusses in detail the various options for satisfying the
   first of the above conditions. Regardless of those mechanisms
   however, agents are certain to have a clear understanding of whether
   their peers support trickle ICE once an Offer and an Answer have been
   exchanged, which also allows for ICE processing to commence (see
   Figure 3).

4.1.1. Asserting dialog state through reliable Offer/Answer delivery

```
            Alice                       Bob
              |                          |
              |      INVITE (Offer)      |
              |------------------------>|
              |       183 (Answer)       |
              |<------------------------|
              |         PRACK/OK         |
              |------------------------>|
              |                          |
      +-------------------------------------------+
      |Alice and Bob know that both can trickle|
      |and know that the dialog is in the early|
      |state. Send INFO!                        |
      +-------------------------------------------+
              |                          |
              |  INFO/OK (+SRFLX Cand.) |
              |------------------------>|
              |  INFO/OK (+SRFLX Cand.) |
              |<------------------------|
              |                          |
```
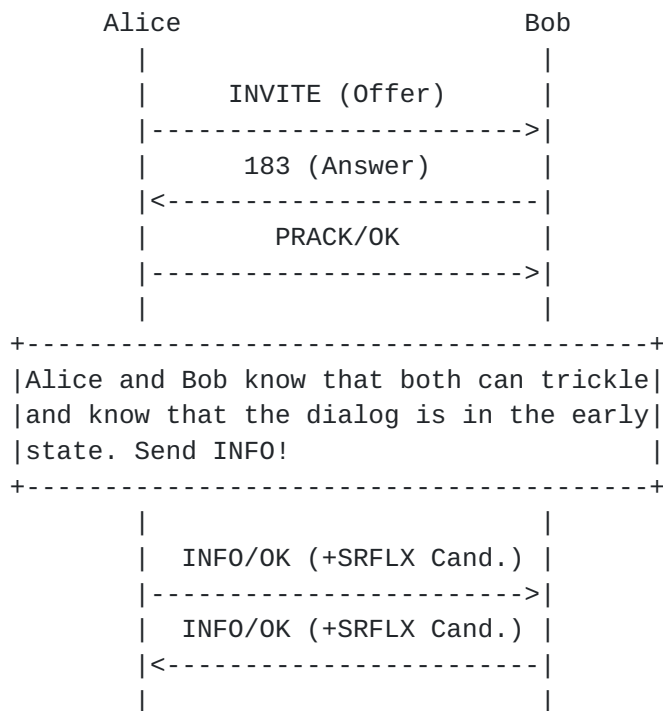
Figure 3: SIP Offerer can freely trickle as soon as it receives an
                             Answer.

   Satisfying both conditions is also relatively trivial for ICE agents
   that have sent an Offer in an INVITE and that have received an Answer
   in a reliable provisional response. It is guaranteed to have
   confirmed support for Trickle ICE within the Answerer (or lack
   thereof) and to have fully initialized the SIP dialog at both ends.
   Offerers and Answerers in the above situation can therefore freely
   commence trickling within the newly established dialog.

4.1.2. Asserting dialog state through unreliable Offer/Answer delivery

   The situation is a bit more delicate for agents that have received an
   Offer in an INVITE request and have sent an Answer in an unreliable
   provisional response because, once the response has been sent, the
   Answerer does not know when or if it has been received (Figure 4).

```
                  Alice                      Bob
                    |                         |
                    |      INVITE (Offer)     |
                    |------------------------>|
                    |        183 (Answer)     |
                    |<------------------------|
                    |                         |
                    |             +----------------------+
                    |             |Bob:  I don't know if |
                    |             |Alice got my 183 or if|
                    |             |her dialog is already |
                    |             |in the early state.   |
                    |             |  Can I send INFO???   |
                    |             +----------------------+
                    |                         |
```
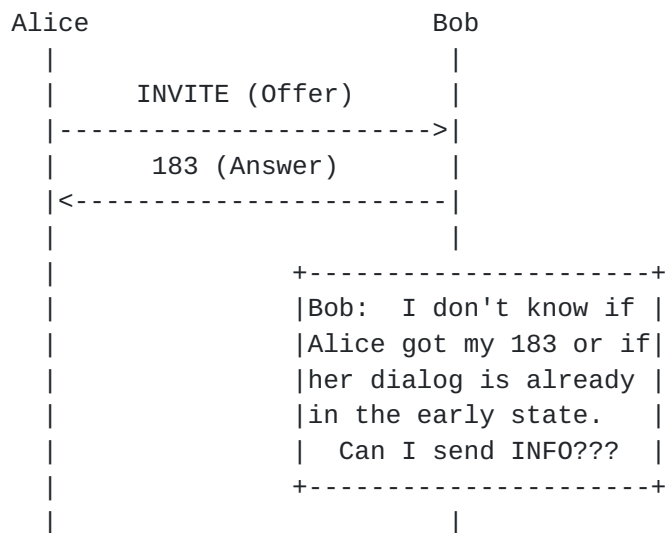
    Figure 4: A SIP UA that sent an Answer in an unreliable provisional
    response does not know if it was received and if the dialog at the
             side of the Offerer has entered the early state

   In order to clear this ambiguity as soon as possible, the answerer
   needs to retransmit the provisional response with the exponential
   back-off timers described in [RFC3262]. These retransmissions MUST
   cease on receipt of a INFO request or on transmission of the answer
   in a 2xx response. This is similar to the procedure described in
   section 13.1.1 of [I-D.ietf-mmusic-ice-sip-sdp] except that the STUN
   binding Request is replaced by the INFO request.

   The Offerer MUST send a Trickle ICE INFO request as soon as it
   receives an SDP Answer in an unreliable provisional response. This
   INFO message MUST repeat the candidates that were already provided in
   the Offer (as would be the case when Half Trickle is performed or
   when new candidates have not been learned since then) and/or they MAY
   also deliver new candidates (if available). An end-of-candidates
   indication MAY be included in case candidate discovery has ended in
   the mean time.

   As soon as an Answerer has received such an INFO request, the
   Answerer has an indication that a dialog is established at both ends
   and MAY begin trickling (Figure 5).

   Note: The +SRFLX in Figure 5 indicates that additionally newly
   learned server-reflexive candidates are included.

```
                     Alice                      Bob
                       |                         |
                       |      INVITE (Offer)     |
                       |------------------------>|
                       |       183 (Answer)      |
                       |<------------------------|
                       |   INFO/OK (+SRFLX Cand.) |
                       |------------------------>|
                       |                         |
                       |             +----------------------+
                       |             |Bob:  Now I know Alice|
                       |             | is ready. Send INFO! |
                       |             +----------------------+
                       |   INFO/OK (+SRFLX Cand.) |
                       |<------------------------|
                       |                         |
                       |     200/ACK (Answer)     |
                       |<------------------------|
```
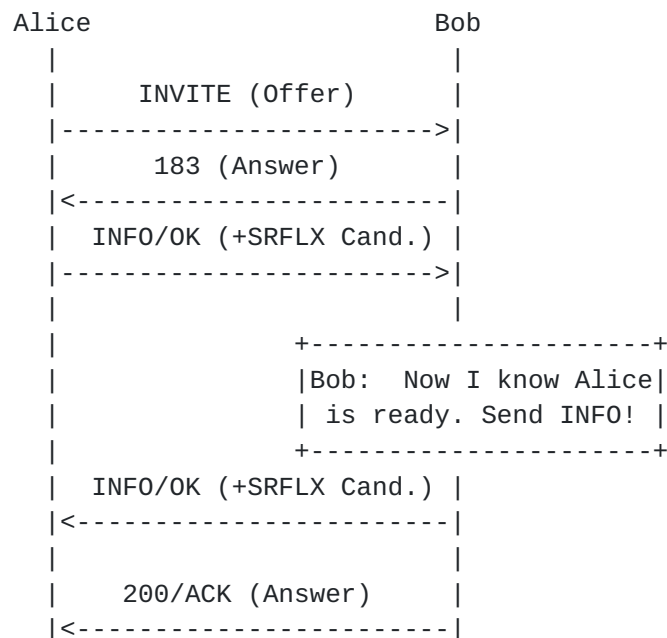
    Figure 5: A SIP UA that received an INFO request after sending an
   unreliable provisional response knows that the dialog at the side of
                 the receiver has entered the early state

   When sending the Answer in the 200 OK response, the Answerer MUST
   repeat exactly the same Answer that was previously sent in the
   unreliable provisional response in order to fulfill the corresponding
   requirements in [RFC3264]. In other words, that Offerer needs to be
   prepared to receive a different number of candidates in that repeated
   Answer than previously exchanged via trickling.

4.1.3. Initiating Trickle ICE without an SDP Answer

   The possibility to convey arbitrary candidates in INFO message bodies
   allows ICE agents to initiate trickling without actually sending an
   Answer. Trickle ICE Agents MAY therefore respond to an INVITE
   request with provisional responses without an SDP Answer. Such
   provisional responses serve for establishing an early dialog.

   Agents that choose to establish the dialog in this way, MUST
   retransmit these responses with the exponential back-off timers
   described in [RFC3262]. These retransmissions MUST cease on receipt
   of an INFO request or on transmission of the answer in a 2xx
   response. This is again similar to the procedure described in
   section 12.1.1 of [I-D.ietf-mmusic-ice-sip-sdp] except that an Answer
   is not yet provided.

   Note: The +SRFLX in Figure 6 indicates that additionally newly
   learned server-reflexive candidates are included.

```
                 Alice                      Bob
                   |                         |
                   |      INVITE (Offer)     |
                   |------------------------>|
                   |         183 (-)         |
                   |<------------------------|
                   |   INFO/OK (SRFLX Cand.) |
                   |------------------------>|
                   |                         |
                   |            +---------------------+
                   |            |Bob:  Now I know again|
                   |            | that Alice is ready. |
                   |            | Send INFO!           |
                   |            +---------------------+
                   |   INFO/OK (SRFLX Cand.) |
                   |<------------------------|
                   |      183 (Answer) opt.  |
                   |<------------------------|
                   |   INFO/OK (SRFLX Cand.) |
                   |<------------------------|
                   |      200/ACK (Answer)   |
                   |<------------------------|
```

       Figure 6: A SIP UA sends an unreliable provisional response without
                an Answer for establishing an early dialog

   When sending the Answer the agent MUST repeat all currently known and
   used candidates, if any, and MAY include all newly gathered
   candidates since the last INFO request was sent. If that Answer was
   sent in a unreliable provisional response, the Answerers MUST repeat
   exactly the same Answer in the 200 OK response in order to fulfill
   the corresponding requirements in [RFC3264]. In other words, an
   Offerer needs to be prepared to receive fewer candidates in that
   repeated Answer than previously exchanged via trickling.

4.1.4. Considerations for 3PCC

   Agents that have sent an Offer in a reliable provisional response and
   that receive an Answer in a PRACK are also in a situation where
   support for Trickle ICE is confirmed and the SIP dialog is guaranteed
   to be in a state that would allow in-dialog INFO requests (see
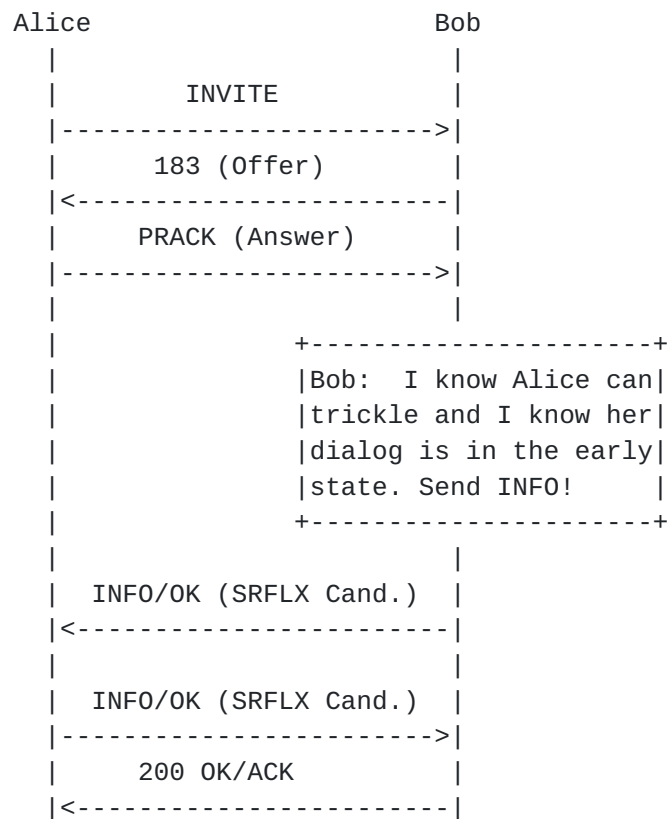   Figure 7).

```
                     Alice                    Bob
                       |                       |
                       |         INVITE        |
                       |---------------------->|
                       |       183 (Offer)     |
                       |<----------------------|
                       |      PRACK (Answer)   |
                       |---------------------->|
                       |                       |
                       |              +----------------------+
                       |              |Bob:  I know Alice can|
                       |              |trickle and I know her|
                       |              |dialog is in the early|
                       |              |state. Send INFO!     |
                       |              +----------------------+
                       |                       |
                       |   INFO/OK (SRFLX Cand.)  |
                       |<----------------------|
                       |                       |
                       |   INFO/OK (SRFLX Cand.)  |
                       |---------------------->|
                       |       200 OK/ACK      |
                       |<----------------------|
```

     Figure 7: A SIP Offerer in a 3PCC scenario can also freely start
               trickling as soon as it receives an Answer.

   Trickle Agents that send an Offer in a 200 OK and receive an Answer
   in an ACK can still create a dialog and confirm support for Trickle
   ICE by sending an unreliable provisional response similar to
   Section 4.1.3. According to [RFC3261], this unreliable response MUST
   NOT contain an Offer.

   The Trickle Agent (at the UAS) retransmits the provisional response
   with the exponential back-off timers described in [RFC3262].
   Retransmits MUST cease on receipt of a INFO request or on
   transmission of the answer in a 2xx response. The peer Trickle Agent
   (at the UAC) MUST send a Trickle ICE INFO request as soon as they
   receive an unreliable provisional response (see Figure 8).
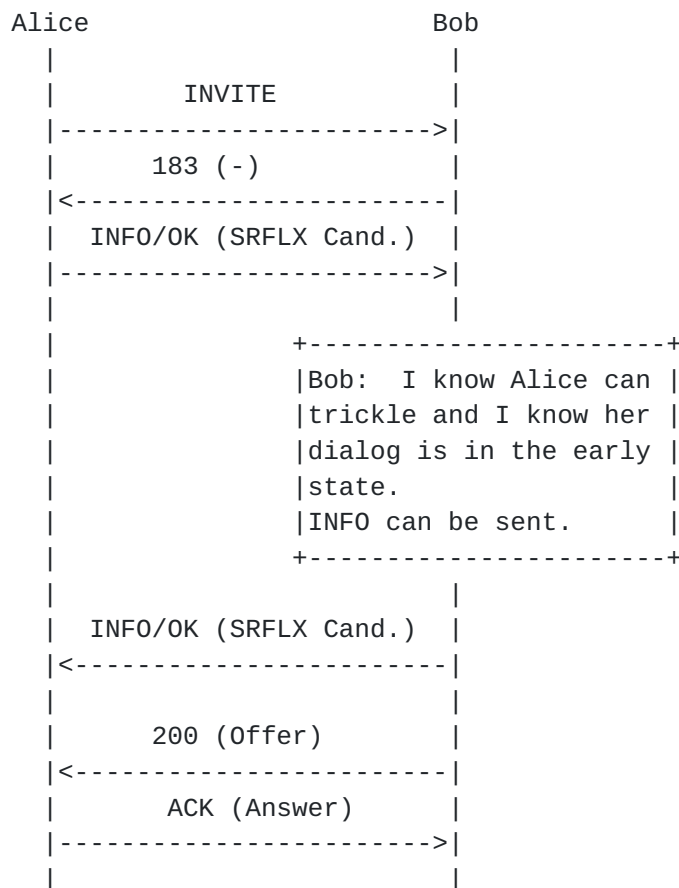
```
                 Alice                        Bob
                   |                           |
                   |           INVITE          |
                   |-------------------------->|
                   |          183 (-)          |
                   |<--------------------------|
                   |   INFO/OK (SRFLX Cand.)    |
                   |-------------------------->|
                   |                           |
                   |              +-----------------------+
                   |              |Bob:  I know Alice can |
                   |              |trickle and I know her |
                   |              |dialog is in the early |
                   |              |state.                 |
                   |              |INFO can be sent.       |
                   |              +-----------------------+
                   |                           |
                   |   INFO/OK (SRFLX Cand.)    |
                   |<--------------------------|
                   |                           |
                   |         200 (Offer)        |
                   |<--------------------------|
                   |         ACK (Answer)       |
                   |-------------------------->|
                   |                           |
```

       Figure 8: A SIP UAC in a 3PCC scenario can also freely start
    trickling as soon as it receives an unreliable provisional response.

4.2. Delivering candidates in INFO messages

   Whenever new ICE candidates become available for sending, agents
   would encode them in "a=candidate" lines as described by
   [I-D.ietf-ice-trickle]. For example:

```
          a=candidate:2 1 UDP 1694498815 192.0.2.3 5000 typ srflx
                  raddr 10.0.1.1 rport 8998
```

   The use of SIP INFO requests happens within the context of the Info
   Package as defined Section 10. The MIME type for their payload MUST
   be set to 'application/trickle-ice-sdpfrag' as defined in Section 9.

   Since neither the "a=candidate" nor the "a=end-of-candidates"
   attributes contain information that would allow correlating them to a
   specific "m=" line, this is handled through the use of pseudo "m="
   lines and identification tags in "a=mid:" attributes as defined in

[RFC5888]. Pseudo "m=" lines follow the SDP syntax for "m=" lines as
defined in [RFC4566], but provide no semantics other than indicating
to which "m=" line a candidate belongs. Consequently, the receiving
agent MUST ignore the remaining content of the pseudo m-line. This
guarantees that the 'application/trickle-ice-sdpfrag' bodies do not
interfere with the Offer/Answer procedures as specified in [RFC3264].

When sending the INFO request, the agent MAY, if already known to the
agent, include the same content into the pseudo m-line as for the
corresponding Offer or Answer. However, since Trickle-ICE might be
decoupled from the Offer/Answer negotiation this content might be
unknown to the agent. In this case, the agent MUST include the
following default values.

o The media is set to 'audio'.

o The port value is set to '9'.

o The proto value is set to 'RTP/AVP'.

o The fmt SHOULD appear only once and is set to '0'

Agents MUST include a pseudo "m=" line and an identification tag in a
"a=mid:" attribute for every "m=" line whose candidate list they
intend to update. Such "a=mid:" attributes MUST immediately precede
the list of candidates for that specific "m=" line. All
"a=candidate" or "a=end-of-candidates" attributes following an
"a=mid:" attribute, up until (and excluding) the next occurrence of
an "a=mid:" attribute, pertain to the "m=" line identified by that
identification tag. An "a=end-of-candidates" attribute, preceding
any "a=mid:" attributes, indicates the end of all trickling from that
agent, as opposed to end of trickling for a specific "m=" line, which
would be indicated by a media level "a=end-of-candidates" attribute.

The use of "a=mid:" attributes allows for a structure similar to the
one in SDP Offers and Answers where separate media-level and session-
level sections can be distinguished. In the current case, lines
preceding any "a=mid:" attributes are considered to be session-level.
Lines appearing in between or after "a=mid:" attributes will be
interpreted as media-level.

   Note that while this specification uses the "a=mid:" attribute
   from [RFC5888], it does not define any grouping semantics.
   Consequently, using the "a=group:" attribute from that same
   specification is neither needed nor used in Trickle ICE for SIP.

All INFO requests MUST carry the "a=ice-pwd:" and "a=ice-ufrag:"
attributes that would allow mapping them to a specific ICE

generation. An agent MUST discard any received INFO requests
containing "a=ice-pwd:" and "a=ice-ufrag:" attributes that do not
match those of the current ICE Negotiation Session.

The "a=ice-pwd:" and "a=ice-ufrag:" attributes MUST appear at the
same level as the ones in the Offer/Answer exchange. In other words,
if they were present as session-level attributes, they will also
appear at the beginning of all INFO message payloads, i.e. preceding
all "a=mid:" attributes. If they were originally exchanged as media
level attributes, potentially overriding session-level values, then
they will also be included in INFO message payloads, following the
corresponding "a=mid:" attribute.

Since the agent is not fully aware of the state of the ICE
Negotiation Session at its peer it MUST include all currently known
and used local candidates in every INFO request. I.e. all candidates
that were previously sent under the same combination of "a=ice-pwd:"
and "a=ice-ufrag:" need to be repeated. Although repeating all
candidates creates some overhead, it also allows easier handling of
problems that could arise from unreliable transports, like e.g. loss
of messages and reordering, which can be detected through the CSeq:
header field in the INFO request.

When receiving INFO requests carrying any candidates, agents will
therefore first identify and discard the attribute lines containing
candidates they have already received in previous INFO requests or in
the Offer/Answer exchange preceding them. Two candidates are
considered to be equal if their IP address port, transport and
component ID are the same. After identifying and discarding known
candidates, the ICE agents will then process the remaining, actually
new candidates according to the rules described in
[I-D.ietf-ice-trickle].

Note: At the time of writing this specification there were ongoing
discussions if a functionality for removing already exchanged
candidates would be useful. Such a functionality is out of the scope
of this specification and most likely needs to be signaled by means
of a yet to be defined ICE extension, although it could in principle
be achieved quite easily, e.g. without anticipating any solution by
simply omitting a previously sent candidate from a subsequent INFO
message. However, if an implementation according to this
specification receives such an INFO message with a missing candidate
it MAY treat that as an exceptional case. Implementing appropriate
recovery procedures at the receiving side is RECOMMENDED for this
situation. Ignoring that a candidate was missing might be a sensible
strategy.

The following example shows the content of one sample candidate
delivering INFO request:

```
INFO sip:alice@example.com SIP/2.0
...
Info-Package: trickle-ice
Content-type: application/sdp
Content-Disposition: Info-Package
Content-length: ...

a=ice-pwd:asd88fgpdd777uzjYhagZg
a=ice-ufrag:8hhY
m=audio 9 RTP/AVP 0
a=mid:1
a=candidate:1 1 UDP 1658497328 192.168.100.33 5000 typ host
a=candidate:2 1 UDP 1658497328 203.0.113.3 5000 typ srflx
        raddr 10.0.1.1 rport 8998
a=end-of-candidates
m=audio 9 RTP/AVP 0
a=mid:2
a=candidate:2 1 UDP 1658497328 203.0.113.3 5002 typ srflx
        raddr 10.0.1.1 rport 9000
a=end-of-candidates
```

5. Initial discovery of Trickle ICE support

SIP User Agents (UAs) that support and intend to use trickle ICE are
REQUIRED by [I-D.ietf-ice-trickle] to indicate that in their Offers
and Answers using the following attribute: "a=ice-options:trickle".
This makes discovery fairly straightforward for Answerers or for
cases where Offers need to be generated within existing dialogs
(i.e., when sending re-INVITE requests). In both scenarios prior SDP
would have provided the necessary information.

Obviously, prior SDP is not available at the time a first Offer is
being constructed and it is therefore impossible for ICE agents to
determine support for incremental provisioning that way. The
following options are suggested as ways of addressing this issue.

5.1. Provisioning support for Trickle ICE

In certain situations it may be possible for integrators deploying
Trickle ICE to know in advance that some or all endpoints reachable
from within the deployment will support Trickle ICE. This is likely
to be the case, for example, for WebRTC clients that will always be

communicating with other WebRTC clients or known Session Border
Controllers (SBC) with support for this specification.

While the exact mechanism for allowing such provisioning is out of
scope here, this specification encourages trickle ICE implementations
to allow the option in the way they find most appropriate.

5.2. Trickle ICE discovery with GRUU

[RFC3840] provides a way for SIP user agents to query for support of
specific capabilities using, among others, OPTIONS requests. GRUU
support on the other hand allows SIP requests to be addressed to
specific UAs (as opposed to arbitrary instances of an address of
record). Combining the two and using the "trickle-ice" option tag
defined in Section 10.6 provides SIP UAs with a way of learning the
capabilities of specific US instances and then addressing them
directly with INVITE requests that require SIP support.

Such targeted trickling may happen in different ways. One option
would be for a SIP UA to learn the GRUU instance ID of a peer through
presence and to then query its capabilities direction with an OPTIONS
request. Alternately, it can also just send an OPTIONS request to
the AOR it intends to contact and then inspect the returned
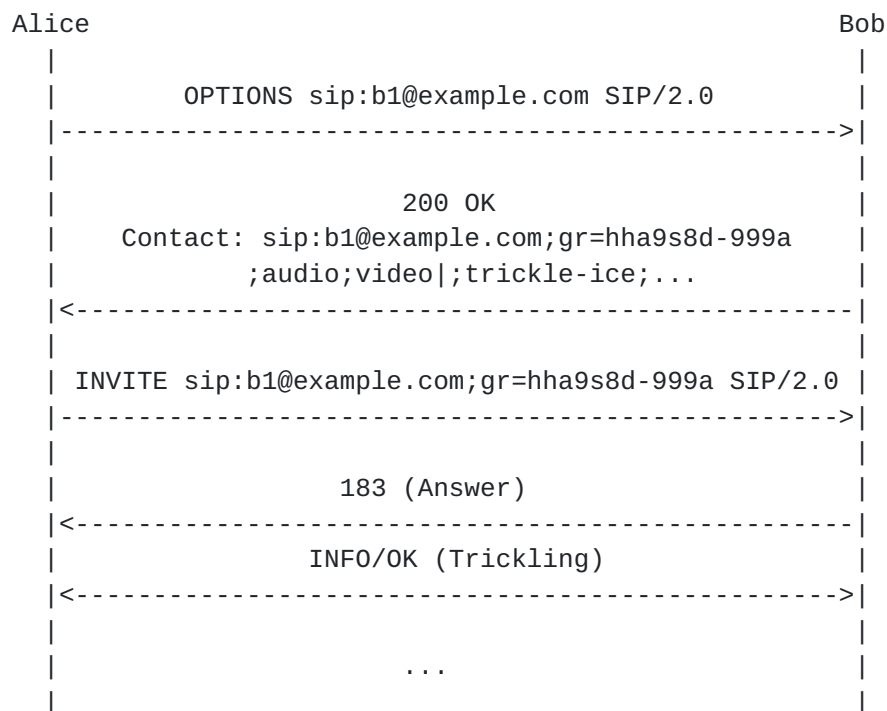response(s) for support of both GRUU and Trickle ICE (Figure 9).

```
          Alice                                            Bob
            |                                               |
            |         OPTIONS sip:b1@example.com SIP/2.0     |
            |---------------------------------------------->|
            |                                               |
            |                    200 OK                     |
            |      Contact: sip:b1@example.com;gr=hha9s8d-999a    |
            |             ;audio;video|;trickle-ice;...     |
            |<----------------------------------------------|
            |                                               |
            | INVITE sip:b1@example.com;gr=hha9s8d-999a SIP/2.0 |
            |---------------------------------------------->|
            |                                               |
            |                   183 (Answer)                |
            |<----------------------------------------------|
            |               INFO/OK (Trickling)             |
            |<--------------------------------------------->|
            |                                               |
            |                      ...                      |
            |                                               |
```

Figure 9: Trickle ICE support discovery with OPTIONS and GRUU

Confirming support for Trickle ICE through [RFC3840] gives SIP UAs
the options to engage in Full Trickle negotiation (as opposed to the
more lengthy Half Trickle) from the very first Offer they send.

5.3. Trickle ICE discovery through other protocols

Protocols like XMPP [RFC6120] define advanced discovery mechanisms
that allow specific features to be queried priory to actually
attempting to use them. Solutions like [RFC7081] define ways of
using SIP and XMPP together which also provides a way for dual stack
SIP+XMPP endpoints to make use of such features and verify Trickle
ICE support for a specific SIP endpoint through XMPP. [TODO expand
on a specific way to do this or declare as out of scope]

5.4. Fall-back to Half Trickle

In cases where none of the other mechanisms in this section are
acceptable, SIP UAs should use the Half Trickle mode defined in
[I-D.ietf-ice-trickle]. With Half Trickle, agents initiate sessions
the same way they would when using Vanilla ICE for SIP
[I-D.ietf-mmusic-ice-sip-sdp]. This means that, prior to actually
sending an Offer, agents would first gather ICE candidates in a
blocking way and then send them all in that Offer. The blocking
nature of the process would likely imply that some amount of latency
will be accumulated and it is advised that agents try to anticipate
it where possible, like for example, when user actions indicate a
high likelihood for an imminent call (e.g., activity on a keypad or a
phone going off-hook).

Using Half Trickle would result in Offers that are compatible with
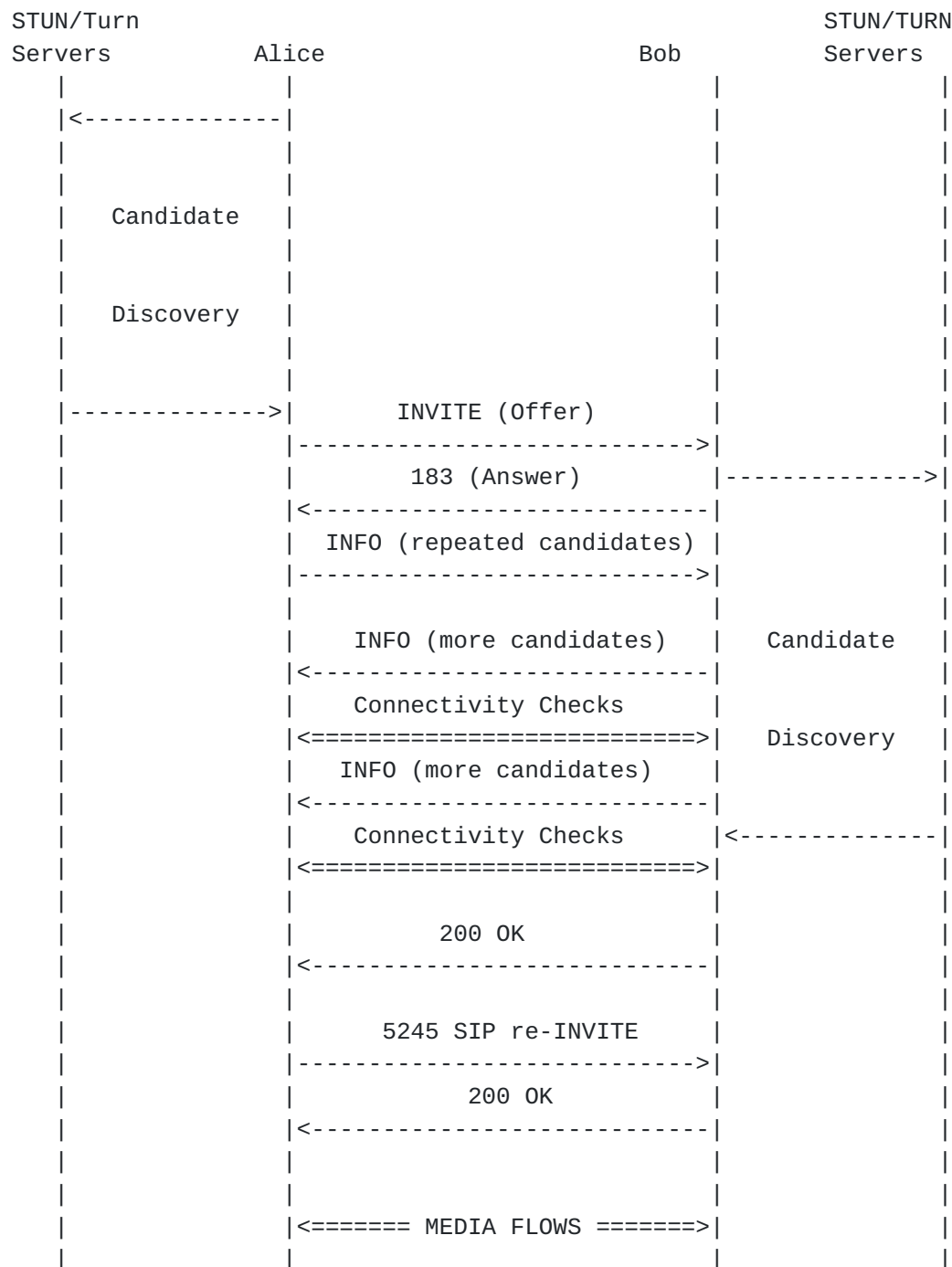both Vanilla ICE SIP endpoints and legacy [RFC3264] endpoints.

```
    STUN/Turn                                    STUN/TURN
    Servers            Alice              Bob     Servers
        |                |                 |         |
        |<--------------|                 |         |
        |                |                 |         |
        |                |                 |         |
        |   Candidate    |                 |         |
        |                |                 |         |
        |                |                 |         |
        |   Discovery    |                 |         |
        |                |                 |         |
        |                |                 |         |
        |-------------->|     INVITE (Offer)        |         |
        |                |---------------------------->|         |
        |                |        183 (Answer)       |-------------->|
        |                |<----------------------------|         |
        |                |  INFO (repeated candidates) |         |
        |                |---------------------------->|         |
        |                |                 |         |
        |                |   INFO (more candidates)  |  Candidate   |
        |                |<----------------------------|         |
        |                |    Connectivity Checks    |         |
        |                |<===========================>|  Discovery   |
        |                |    INFO (more candidates)  |         |
        |                |<----------------------------|         |
        |                |    Connectivity Checks    |<--------------|
        |                |<===========================>|         |
        |                |                 |         |
        |                |        200 OK        |         |
        |                |<----------------------------|         |
        |                |                 |         |
        |                |     5245 SIP re-INVITE    |         |
        |                |---------------------------->|         |
        |                |        200 OK        |         |
        |                |<----------------------------|         |
        |                |                 |         |
        |                |                 |         |
        |                |<======= MEDIA FLOWS =======>|         |
        |                |                 |         |
```

      Figure 10: Example - A typical (Half) Trickle ICE exchange with SIP

   It is worth reminding that once a single Offer or Answer had been
   exchanged within a specific dialog, support for Trickle ICE will have
   been determined. No further use of Half Trickle will therefore be
   necessary within that same dialog and all subsequent exchanges can
   use the Full Trickle mode of operation.

6. Considerations for RTP and RTCP multiplexing

   The following consideration describe options for Trickle-ICE in order
   to give some guidance to implementors on how trickling can be
   optimized with respect to providing RTCP candidates.

   Handling of the "a=rtcp" attribute [RFC3605] and the "a=rtcp-mux"
   attribute for RTP/RTCP multiplexing [RFC5761] is already considered
   in section 4.2. of [I-D.ietf-mmusic-ice-sip-sdp], respectively, as
   well in [RFC5761] itself. These considerations are still valid for
   Trickle ICE, however, trickling provides more flexibility for the
   sequence of candidate exchange in case of RTCP multiplexing.

   If the Offerer supports RTP/RTCP multiplexing exclusively as
   specified in [I-D.ietf-mmusic-mux-exclusive], the procedures in that
   document apply for the handling of the "a=rtcp-mux-only", "a=rtcp"
   and the "a=rtcp-mux" attributes.

   While a Half Trickle Offerer would have to send an offer compliant to
   [I-D.ietf-mmusic-ice-sip-sdp] and [RFC5761] including candidates for
   all components, this flexibility allows a Full Trickle Offerer to
   initially send only RTP candidates (component 1) if it assumes that
   RTCP multiplexing is supported by the Answerer. A Full Trickle
   Offerer would need to start gathering and trickling RTCP candidates
   (component 2) only after having received an indication in the answer
   that the answerer unexpectedly does not support RTCP multiplexing.

   A Trickle answerer MAY include an "a=rtcp-mux" attribute [RFC5761] in
   the application/trickle-ice-sdpfrag body it supports and uses RTP and
   RTCP multiplexing. Trickle answerer MUST follow the guidance on the
   usage of the "a=rtcp" attribute as given in
   [I-D.ietf-mmusic-ice-sip-sdp] and Receipt of this attribute at the
   Offerer in an INFO request prior to the Answer indicates that the
   Answerer supports and uses RTP and RTCP multiplexing. The Offerer
   can use this information e.g. for stopping gathering of RTCP
   candidates and/or for freeing corresponding resources.

   This behavior is illustrated by the following example offer that
   indicates support for RTP and RTCP multiplexing.

```
        v=0
        o=alice 2890844526 2890844526 IN IP4 atlanta.example.com
        s=
        c=IN IP4 atlanta.example.com
        t=0 0
        a=ice-pwd:777uzjYhagZgasd88fgpdd
        a=ice-ufrag:Yhh8
        m=audio 10000 RTP/AVP 0
        a=mid:1
        a=rtcp-mux
        a=candidate:1 1 UDP 1658497328 192.168.100.33 5000 typ host
```

Once the dialog is established as described in section Section 4.1
the Answerer sends the following INFO message.

```
        INFO sip:alice@example.com SIP/2.0
        ...
        Info-Package: trickle-ice
        Content-type: application/sdp
        Content-Disposition: Info-Package
        Content-length: ...

        a=ice-pwd:asd88fgpdd777uzjYhagZg
        a=ice-ufrag:8hhY
        m=audio 9 RTP/AVP 0
        a=mid:1
        a=rtcp-mux
        a=candidate:1 1 UDP 1658497328 192.168.100.33 5000 typ host
```

This INFO message indicates that the Answerer supports and uses RTP
and RTCP multiplexing as well. This allows the Offerer to omit
gathering of RTCP candidates or releasing already gathered RTCP
candidates. If the INFO message did not contain the a=rtcp-mux
attribute, the Offerer would have to gather RTCP candidates unless it
wants to wait until receipt of an Answer that eventually confirms
support or non-support for RTP and RTCP multiplexing.

7. Considerations for Media Multiplexing

The following consideration describe options for Trickle-ICE in order
to give some guidance to implementors on how trickling can be
optimized with respect to providing candidates in case of Media
Multiplexing [I-D.ietf-mmusic-sdp-bundle-negotiation]. It is assumed
that the reader is familiar with
[I-D.ietf-mmusic-sdp-bundle-negotiation].

ICE candidate exchange is already considered in section 11 of
[I-D.ietf-mmusic-sdp-bundle-negotiation]. These considerations are
still valid for Trickle ICE, however, trickling provides more
flexibility for the sequence of candidate exchange, especially in
Full Trickle mode.

Except for bundle-only m-lines, a Half Trickle Offerer would have to
send an offer with candidates for all bundled m-lines. The
additional flexibility, however, allows a Full Trickle Offerer to
initially send only candidates for the m-line with the suggested
Offerer BUNDLE address.

Latest on receipt of the answer, the Offerer will detect if BUNDLE is
supported and if the suggested Offerer BUNDLE address was selected.
In this case the Offerer does not need to trickle further candidates
for the remaining m-lines in a bundle. However, if BUNDLE is not
supported, the Full Trickle Offerer needs to gather and trickle
candidates for the remaining m-lines as necessary. If the answerer
selects a Offerer BUNDLE address different from suggested Offerer
BUNDLE address, the Full Trickle Offerer needs to gather and trickle
candidates for the m-line that carries the selected Offerer BUNDLE
address.

A Trickle Answerer SHOULD include an "a=group: BUNDLE" attribute
[I-D.ietf-mmusic-sdp-bundle-negotiation] in the application/trickle-
ice-sdpfrag body if it supports and uses bundling. When doing so,
the Answerer MUST include all identification-tags in the same order
that is used or will be used in the Answer.

Receipt of this attribute at the Offerer in an INFO request prior to
the Answer indicates that the Answerer supports and uses bundling.
The Offerer can use this information e.g. for stopping the gathering
of candidates for the remaining m-lines in a bundle and/or for
freeing corresponding resources.

This behaviour is illustrated by the following example offer that
indicates support for Media Multiplexing.

```
v=0
o=alice 2890844526 2890844526 IN IP4 atlanta.example.com
s=
c=IN IP4 atlanta.example.com
t=0 0
a=group:BUNDLE foo bar
a=ice-pwd:777uzjYhagZgasd88fgpdd
a=ice-ufrag:Yhh8
m=audio 10000 RTP/AVP 0
a=mid:foo
a=rtpmap:0 PCMU/8000
a=extmap 1 urn:ietf:params:rtp-hdrext:sdes:mid
m=video 10002 RTP/AVP 31
a=mid:bar
a=rtpmap:31 H261/90000
a=extmap 1 urn:ietf:params:rtp-hdrext:sdes:mid
```

Once the dialog is established as described in section Section 4.1 the Answerer sends the following INFO message.

```
INFO sip:alice@example.com SIP/2.0
...
Info-Package: trickle-ice
Content-type: application/sdp
Content-Disposition: Info-Package
Content-length: ...

a=group:BUNDLE foo bar
a=ice-pwd:asd88fgpdd777uzjYhagZg
a=ice-ufrag:8hhY
m=audio 9 RTP/AVP 0
a=mid:1
a=rtcp-mux
a=candidate:1 1 UDP 1658497328 192.168.100.33 5000 typ host
m=audio 9 RTP/AVP 0
a=mid:bar
```

This INFO message indicates that the Answerer supports and uses Media Multiplexing as well. Note, that the second m-line shows the default values as specified in section Section 4.2, e.g. media set 'audio' although 'video' was offered. The receiving ICE agents needs to ignore these default values in the pseudo m-lines.

The INFO message also indicates that the Answerer accepted the
suggested Offerer Bundle Address. This allows the Offerer to omit
gathering of RTP and RTCP candidates for the other m-lines or
releasing already gathered candidates. If the INFO message did not
contain the a=group:BUNDLE attribute, the Offerer would have to
gather RTP and RTCP candidates for the other m-lines unless it wants
to wait until receipt of an Answer that eventually confirms support
or non-support for Media Multiplexing.

Independent of using Full Trickle or Half Trickle mode, the rules
from [I-D.ietf-mmusic-sdp-mux-attributes] apply to both, Offerer and
Answerer, when putting attributes in the application/trickle-ice-
sdpfrag body.

8. SDP 'end-of-candidate' Attribute

This section defines a new SDP media-level and session-level
attribute [RFC4566] 'end-of-candidate'. 'end-of-candidate' is a
property attribute [RFC4566], and hence has no value. By including
this attribute in an Offer or Answer the sending agent indicates that
it will not trickle further candidates. The detailed SDP Offer/
Answer procedures for the 'end-of-candidate' attribute are specified
in [I-D.ietf-ice-trickle].

   Name: end-of-candidate

   Value: N/A

   Usage Level: media and session-level

   Charset Dependent: no

   Mux Category: IDENTICAL

   Example: a=end-of-candidate

9. Content Type 'application/trickle-ice-sdpfrag'

9.1. Overall Description

A application/trickle-ice-sdpfrag body is used by the Trickle-ICE
Info Package. It uses a subset of the possible SDP lines as defined
by the grammar defined in [RFC4566]. A valid body uses only media
descriptions and certain attributes that are needed and/or useful for
trickling candidates. The content adheres to the following grammar.

9.2. Grammar

   The grammar of an 'application/trickle-ice-sdpfrag' body is based the
   following ABNF [RFC5234]. It specifies the subset of existing SDP
   attributes, that are needed or useful for trickling candidates.

```
        ;   Syntax
        trickle-ice-sdpfrag =   session-level-fields
                          pseudo-media-descriptions
        session-level-fields = [bundle-group-attribute CRLF]
                          [ice-lite-attribute CRLF]
                          ice-pwd-attribute CRLF
                          ice-ufrag-attribute CRLF
                          [ice-options-attribute CRLF]
                          [ice-pacing-attribute CRLF]
                          [end-of-candidates-attribute CRLF]
                          extension-attribute-fields
                                ; for future extensions

        ice-lite-attribute      = %s"a=" ice-lite
        ice-pwd-attribute       = %s"a=" ice-pwd-att
        ice-ufrag-attribute     = %s"a=" ice-ufrag-att
        ice-pacing-attribute =     %s"a="  ice-pacing-att
        ice-options-attribute =     %s"a="  ice-options
        bundle-group-attribute = "a=group:" bundle-semantics
                                  *(SP identification-tag)
        bundle-semantics = "BUNDLE"
        end-of-candidates-attribute  = %s"a=" end-of-candidates
        extension-attribute-fields   = attribute-fields

        pseudo-media-descriptions    =  *( media-field
                               trickle-ice-attribute-fields
                             [extension-attribute-fields] )
                                  ; for future extensions
        trickle-ice-attribute-fields =  mid-attribute CRLF
                              ["a=rtcp-mux" CRLF]
                              ["a=rtcp-mux-only" CRLF]
                              *(candidate-attributes CRLF)
                              [ice-pwd-attribute CRLF]
                              [ice-ufrag-attribute CRLF]
                              [remote-candidate-attribute CRLF]
                              [end-of-candidates-attribute CRLF]
        remote-candidate-attribute   = %s"a=" remote-candidate-att
        candidate-attributes         = %s"a=" candidate-attribute
        end-of-candidates            = %s"end-of-candidates"
```

   with ice-lite, ice-pwd-att, remote-candidate-att, ice-ufrag-att, ice-
   pacing-att, ice-options, candidate-attribute remote-candidate-att

from [I-D.ietf-mmusic-ice-sip-sdp], identification-tag, mid-attribute
; from [RFC5888], media-field, attribute-fields from [RFC4566]. The
indicator for case-sensitivity %s is defined in [RFC7405].

An Agent MUST ignore any received unknown extension-attribute-fields.

10. Info Package

10.1. Rationale - Why INFO?

The decision to use SIP INFO requests as a candidate transport method
is based primarily on their lightweight nature. Once a dialog has
been established, INFO messages can be exchanged both ways with no
restrictions on timing and frequency and no risk of collision.

On the other hand, using Offer/Answer and UPDATE requests [RFC3311]
introduces the following complications:

Blocking of messages: [RFC3264] defines Offer/Answer as a strictly
   sequential mechanism. There can only be a maximum of one exchange
   at any point of time. Both sides cannot simultaneously send
   Offers nor can they generate multiple Offers prior to receiving an
   Answer. Using UPDATE requests for candidate transport would
   therefore imply the implementation of a candidate pool at every
   agent where candidates can be stored until it is once again that
   agent's "turn" to emit an Answer or a new Offer. Such an approach
   would introduce non-negligible complexity for no additional value.

Elevated risk of glare: The sequential nature of Offer/Answer also
   makes it impossible for both sides to send Offers simultaneously.
   What's worse is that there are no mechanisms in SIP to actually
   prevent that. [RFC3261], where the situation of Offers crossing
   on the wire is described as "glare", only defines a procedure for
   addressing the issue after it has occurred. According to that
   procedure both Offers are invalidated and both sides need to retry
   the negotiation after a period between 0 and 4 seconds. The high
   likelihood for glare to occur and the average two second back-off
   intervals would imply Trickle ICE processing duration would not
   only fail to improve but actually exceed those of Vanilla ICE.

INFO messages decouple the exchange of candidates from the Offer/
Answer negotiation and are subject to none of the glare issues
described above, which makes them a very convenient and lightweight
mechanism for asynchronous delivery of candidates.

Using in-dialog INFO messages also provides a way of guaranteeing
that candidates are delivered end-to-end, between the same entities
that are actually in the process of initiating a session. Out-of-

dialog alternatives would have implied requiring support for Globally
Routable UA URI (GRUU) [RFC5627] which, given GRUUs relatively low
adoption levels, would have constituted too strong of constraint to
the adoption of Trickle ICE.

10.2. Overall Description

This specification defines an Info Package for use by SIP user agents
implementing Trickle ICE. INFO requests carry ICE candidates
discovered after the peer user agents have confirmed mutual support
for Trickle ICE.

10.3. Applicability

The purpose of the ICE protocol is to establish a media path in the
presence of NAT and firewalls. The candidates are transported in
INFO requests and are part of this establishment.

Candidates sent by a Trickle ICE agent after the Offer, follow the
same signaling path and reach the same entity as the Offer itself.
While it is true that GRUUs can be used to achieve this, one of the
goals of this specification is to allow operation of Trickle ICE in
as many environments as possible including those without GRUU
support. Using out-of-dialog SUBSCRIBE/NOTIFY requests would not
satisfy this goal.

10.4. Info Package Name

This document defines a SIP Info Package as per [RFC6086]. The Info
Package token name for this package is "trickle-ice"

10.5. Info Package Parameters

This document does not define any Info Package parameters.

10.6. SIP Option Tags

[RFC6086] allows Info Package specifications to define SIP option-
tags. This specification extends the option-tag construct of the SIP
grammar as follows:

```
 option-tag /= "trickle-ice"
```

SIP entities that support this specification MUST place the 'trickle-
ice' option-tag in a SIP Supported: header field within all SIP
INVITE requests and responses.

When responding to, or generating a SIP OPTIONS request a SIP entity
MUST also include the 'trickle-ice' option-tag in a SIP Supported:
header field.

10.7. Info Message Body Parts

Entities implementing this specification MUST include a payload of
type 'application/trickle-ice-sdpfrag' as defined in Section 9.2 all
SIP INFO requests. The payload is used to convey SDP encoded ICE
candidates.

10.8. Info Package Usage Restrictions

This document does not define any Info Package Usage Restrictions.

10.9. Rate of INFO Requests

A Trickle ICE Agent with many network interfaces might create a high
rate of INFO requests if every newly detected candidate is trickled
individually without aggregation. Implementor that are concerned
about loss of packets in such a case might consider aggregating ICE
candidates and sending INFOS only at some configurable intervals.

10.10. Info Package Security Considerations

See Section 12

11. IANA Considerations

[RFC EDITOR NOTE: Please replace RFCXXXX with the RFC number of this
document. Please replace "I-D.ietf-ice-trickle" with the RFC number
of that document.]

11.1. SDP 'end-of-candidate' Attribute

This section defines a new SDP media-level and session-level
attribute [RFC4566] , 'end-of-candidate'. 'end-of-candidate' is a
property attribute [RFC4566] , and hence has no value.

     Name: end-of-candidate

     Value: N/A

     Usage Level: media and session

     Charset Dependent: no

     Purpose: The sender indicates that it will not trickle
              further candidates.

     O/A Procedures: "I-D.ietf-ice-trickle" defines the detailed
                     SDP Offer/Answer procedures for
                     the 'end-of-candidate' attribute.

     Mux Category: IDENTICAL

     Reference: RFCXXXX

     Example:

     a=end-of-candidate

11.2. application/trickle-ice-sdpfrag MIME Type

     Type name: application

     Subtype name: trickle-ice-sdpfrag

     Required parameters: None.

     Optional parameters: None.

     Encoding considerations:

        SDP files are primarily UTF-8 format text. Although the
        initially defined content of a trickle-ice-sdpfrag body does
        only include ASCII characters, UTF-8 encoded content might be
        introduced via extension attributes. The "a=charset:"
        attribute may be used to signal the presence of other character
        sets in certain parts of a trickle-ice-sdpfrag body (see
        [RFC4566]). Arbitrary binary content cannot be directly
        represented in SDP or a trickle-ice-sdpfrag body.

     Security considerations:

See [RFC4566]) and RFCXXXX

Interoperability considerations:

   See RFCXXXX

Published specification:

   See RFCXXXX

Applications which use this media type:

   Voice over IP, video teleconferencing, streaming media, instant
   messaging, Trickle-ICE among others.

Additional information:

Magic number(s): none

File extension(s): none

Macintosh File Type Code(s): none

Person and email address to contact for further information:

   IETF MMUSIC working group mmusic@ietf.org

Intended usage:

   Trickle-ICE for SIP as specified in RFCXXXX.

Author/Change controller:

   IETF MMUSIC working group mmusic@ietf.org

11.3. SIP Info Package 'trickle-ice'

   This document defines a new SIP Info Package named 'trickle-ice' and
   updates the Info Packages Registry with the following entry.

       +-------------+-----------+
       | Name | Reference |
       +-------------+-----------+
       | trickle-ice | [RFCXXXX] |
       | | |
       +-------------+-----------+

11.4. SIP Option Tag 'trickle-ice'

   This specification registers a new SIP option tag 'trickle-ice' as
   per the guidelines in Section 27.1 of [RFC3261] and updates the
   "Option Tags" section of the SIP Parameter Registry with the
   following entry:

       +-------------+-----------------------------------+-----------+
       | Name | Description | Reference |
       +-------------+-----------------------------------+-----------+
       | trickle-ice | This option tag is used to indicate | [RFCXXXX] |
       | | that a UA supports and understands | |
       | | Trickle-ICE. | |
       +-------------+-----------------------------------+-----------+

12. Security Considerations

   The Security Considerations of [I-D.ietf-mmusic-ice-sip-sdp],
   [RFC6086], [I-D.ietf-ice-trickle] apply. This document clarifies how
   the above specifications are used together for trickling candidates
   and does not create addtitional security risks.

13. Acknowledgements

   The authors would like to thank Ayush Jain, Paul Kyzivat, Jonathan
   Lennox, Simon Perreault and Martin Thomson for reviewing and/or
   making various suggestions for improvements and optimizations.

14. Change Log

[RFC EDITOR NOTE: Please remove this section when publishing].

Changes from draft-ietf-mmusic-trickle-ice-sip-01

o Editorial Clean up

o IANA Consideration added

o Security Consideration added

o RTCP and BUNDLE Consideration added with rules for including
   "a=rtcp-mux" and "a=group: BUNDLLE" attributes

o 3PCC Consideration added

o Clarified that 18x w/o answer is sufficient to create a dialog
   that allows for trickling to start

o Added remaining Info Package definition sections as outlined in
   section 10 of [RFC6086]

o Added definition of application/sdpfrag making draft-ivov-mmusic-
   sdpfrag obsolete

o Added pseudo m-lines as additional separator in sdpfrag bodies for
   Trickle ICE

o Added ABNF for sdp-frag bodies and Trickle-ICE package

Changes from draft-ietf-mmusic-trickle-ice-sip-02

o Removed definition of application/sdpfrag

o Replaced with new type application/trickle-ice-sdpfrag

o RTCP and BUNDLE Consideration enhanced with some examples

o draft-ietf-mmusic-sdp-bundle-negotiation and RFC5761 changed to
   normative reference

o Removed reference to 4566bis

o Addressed review comment from Simon Perreault

Changes from draft-ietf-mmusic-trickle-ice-sip-03

o replaced reference to RFC5245 with draft-ietf-mmusic-rfc5245bis
   and draft-ietf-mmusic-ice-sip-sdp

o Corrected Figure 10, credits to Ayush Jain for finding the bug

o Referencing a=rtcp and a=rtcp-mux handling from draft-ietf-mmusic-
   ice-sip-sdp

o Referencing a=rtcp-mux-exclusive handling from draft-ietf-mmusic-
   mux-exclusive, enhanced ABNF to support a=rtcp-mux-exclusive

o Clarifying that draft-ietf-mmusic-sdp-mux-attributes applies for
   the application/trickle-ice-sdpfrag body

Changes from draft-ietf-mmusic-trickle-ice-sip-04

o considered comments from Christer Holmberg

o corrected grammar for INFO package, such that ice-ufrag/pwd are
   also allowed on media-level as specified in
   [I-D.ietf-mmusic-ice-sip-sdp]

o Added new ice-pacing-attribute fom [I-D.ietf-mmusic-ice-sip-sdp]

o Added formal definition for the end-of-candidates attribute

Changes from draft-ietf-mmusic-trickle-ice-sip-05

o considered further comments from Christer Holmberg

o editorial comments on section 3 addressed

o moved section 3.1 to section 10.1 and applied some edits

o replaced the term "previously sent candidates" with "currently
   known and used candidates".

Changes from draft-ietf-mmusic-trickle-ice-sip-06

o editorial fixes

o additional text on the content of the INFO messages.

o recommendation on what to do if a previously sent candidate is
   unexpectedly missing in a subsequent INFO

o terminology alignment with draft-ietf-ice-trickle-07

15. References

15.1. Normative References

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