

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: October 17, 2018

E. Ivov  
Atlassian  
E. Rescorla  
RTFM, Inc.  
J. Uberti  
Google  
P. Saint-Andre  
Mozilla  
April 15, 2018

Trickle ICE: Incremental Provisioning of Candidates for the Interactive  
Connectivity Establishment (ICE) Protocol

[draft-ietf-ice-trickle-21](#)

#### Abstract

This document describes "Trickle ICE", an extension to the Interactive Connectivity Establishment (ICE) protocol that enables ICE agents to begin connectivity checks while they are still gathering candidates, by incrementally exchanging candidates over time instead of all at once. This method can considerably accelerate the process of establishing a communication session.

#### Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on October 17, 2018.

#### Copyright Notice

Copyright (c) 2018 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents

(<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

- [1.](#) Introduction . . . . . [3](#)
- [2.](#) Terminology . . . . . [5](#)
- [3.](#) Determining Support for Trickle ICE . . . . . [6](#)
- [4.](#) Generating the Initial ICE Description . . . . . [7](#)
- [5.](#) Handling the Initial ICE Description and Generating the Initial ICE Response . . . . . [7](#)
- [6.](#) Handling the Initial ICE Response . . . . . [8](#)
- [7.](#) Forming Check Lists . . . . . [8](#)
- [8.](#) Performing Connectivity Checks . . . . . [8](#)
- [9.](#) Gathering and Conveying Newly Gathered Local Candidates . . . . . [9](#)
- [10.](#) Pairing Newly Gathered Local Candidates . . . . . [10](#)
- [11.](#) Receiving Trickled Candidates . . . . . [11](#)
- [12.](#) Inserting Trickled Candidate Pairs into a Check List . . . . . [12](#)
- [13.](#) Generating an End-of-Candidates Indication . . . . . [16](#)
- [14.](#) Receiving an End-of-Candidates Indication . . . . . [17](#)
- [15.](#) Subsequent Exchanges and ICE Restarts . . . . . [18](#)
- [16.](#) Half Trickle . . . . . [18](#)
- [17.](#) Preserving Candidate Order while Trickling . . . . . [19](#)
- [18.](#) Requirements for Using Protocols . . . . . [20](#)
- [19.](#) IANA Considerations . . . . . [21](#)
- [20.](#) Security Considerations . . . . . [21](#)
- [21.](#) Acknowledgements . . . . . [21](#)
- [22.](#) References . . . . . [22](#)
  - [22.1.](#) Normative References . . . . . [22](#)
  - [22.2.](#) Informative References . . . . . [22](#)
- [Appendix A.](#) Interaction with Regular ICE . . . . . [23](#)
- [Appendix B.](#) Interaction with ICE Lite . . . . . [25](#)
- [Appendix C.](#) Changes from Earlier Versions . . . . . [26](#)
  - [C.1.](#) Changes from [draft-ietf-ice-trickle-20](#) . . . . . [26](#)
  - [C.2.](#) Changes from [draft-ietf-ice-trickle-19](#) . . . . . [26](#)
  - [C.3.](#) Changes from [draft-ietf-ice-trickle-18](#) . . . . . [26](#)
  - [C.4.](#) Changes from [draft-ietf-ice-trickle-17](#) . . . . . [27](#)
  - [C.5.](#) Changes from [draft-ietf-ice-trickle-16](#) . . . . . [27](#)
  - [C.6.](#) Changes from [draft-ietf-ice-trickle-15](#) . . . . . [27](#)
  - [C.7.](#) Changes from [draft-ietf-ice-trickle-14](#) . . . . . [27](#)
  - [C.8.](#) Changes from [draft-ietf-ice-trickle-13](#) . . . . . [27](#)
  - [C.9.](#) Changes from [draft-ietf-ice-trickle-12](#) . . . . . [27](#)
  - [C.10.](#) Changes from [draft-ietf-ice-trickle-11](#) . . . . . [28](#)



<a href="#">C.11</a> . Changes from <a href="#">draft-ietf-ice-trickle-10</a> . . . . .	<a href="#">28</a>
<a href="#">C.12</a> . Changes from <a href="#">draft-ietf-ice-trickle-09</a> . . . . .	<a href="#">28</a>
<a href="#">C.13</a> . Changes from <a href="#">draft-ietf-ice-trickle-08</a> . . . . .	<a href="#">28</a>
<a href="#">C.14</a> . Changes from <a href="#">draft-ietf-ice-trickle-07</a> . . . . .	<a href="#">28</a>
<a href="#">C.15</a> . Changes from <a href="#">draft-ietf-ice-trickle-06</a> . . . . .	<a href="#">28</a>
<a href="#">C.16</a> . Changes from <a href="#">draft-ietf-ice-trickle-05</a> . . . . .	<a href="#">28</a>
<a href="#">C.17</a> . Changes from <a href="#">draft-ietf-ice-trickle-04</a> . . . . .	<a href="#">29</a>
<a href="#">C.18</a> . Changes from <a href="#">draft-ietf-ice-trickle-03</a> . . . . .	<a href="#">29</a>
<a href="#">C.19</a> . Changes from <a href="#">draft-ietf-ice-trickle-02</a> . . . . .	<a href="#">29</a>
<a href="#">C.20</a> . Changes from <a href="#">draft-ietf-ice-trickle-01</a> . . . . .	<a href="#">29</a>
<a href="#">C.21</a> . Changes from <a href="#">draft-ietf-ice-trickle-00</a> . . . . .	<a href="#">29</a>
<a href="#">C.22</a> . Changes from <a href="#">draft-mmusic-trickle-ice-02</a> . . . . .	<a href="#">29</a>
<a href="#">C.23</a> . Changes from <a href="#">draft-ivov-01</a> and <a href="#">draft-mmusic-00</a> . . . . .	<a href="#">30</a>
<a href="#">C.24</a> . Changes from <a href="#">draft-ivov-00</a> . . . . .	<a href="#">30</a>
<a href="#">C.25</a> . Changes from <a href="#">draft-rescorla-01</a> . . . . .	<a href="#">31</a>
<a href="#">C.26</a> . Changes from <a href="#">draft-rescorla-00</a> . . . . .	<a href="#">32</a>
Authors' Addresses . . . . .	<a href="#">32</a>

## 1. Introduction

The Interactive Connectivity Establishment (ICE) protocol [[rfc5245bis](#)] describes how an ICE agent gathers candidates, exchanges candidates with a peer ICE agent, and creates candidate pairs. Once the pairs have been gathered, the ICE agent will perform connectivity checks, and eventually nominate and select pairs that will be used for sending and receiving data within a communication session.

Following the procedures in [[rfc5245bis](#)] can lead to somewhat lengthy establishment times for communication sessions, because candidate gathering often involves querying STUN servers [[RFC5389](#)] and allocating relayed candidates using TURN servers [[RFC5766](#)]. Although many ICE procedures can be completed in parallel, the pacing requirements from [[rfc5245bis](#)] still need to be followed.

This document defines "Trickle ICE", a supplementary mode of ICE operation in which candidates can be exchanged incrementally as soon as they become available (and simultaneously with the gathering of other candidates). Connectivity checks can also start as soon as candidate pairs have been created. Because Trickle ICE enables candidate gathering and connectivity checks to be done in parallel, the method can considerably accelerate the process of establishing a communication session.

This document also defines how to discover support for Trickle ICE, how the procedures in [[rfc5245bis](#)] are modified or supplemented when using Trickle ICE, and how a Trickle ICE agent can interoperate with an ICE agent compliant to [[rfc5245bis](#)].



This document does not define any protocol-specific usage of Trickle ICE. Instead, protocol-specific details for Trickle ICE are defined in separate usage documents. Examples of such documents are [\[I-D.ietf-mmusic-trickle-ice-sip\]](#) (which defines usage with the Session Initiation Protocol (SIP) [\[RFC3261\]](#) and the Session Description Protocol [\[RFC3261\]](#)) and [\[XEP-0176\]](#) (which defines usage with XMPP [\[RFC6120\]](#)). However, some of the examples in the document use SDP and the offer/answer model [\[RFC3264\]](#) to explain the underlying concepts.

The following diagram illustrates a successful Trickle ICE exchange with a using protocol that follows the offer/answer model:

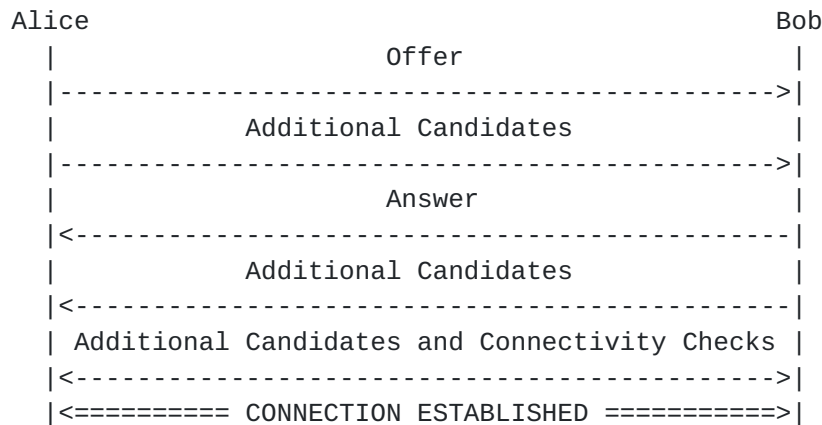


Figure 1: Flow

The main body of this document is structured to describe the behavior of Trickle ICE agents in roughly the order of operations and interactions during an ICE session:

1. Determining support for trickle ICE
2. Generating the initial ICE description
3. Handling the initial ICE description and generating the initial ICE response
4. Handling the initial ICE response
5. Forming check lists, pruning candidates, performing connectivity checks, etc.



6. Gathering and conveying candidates after the initial ICE description and response
7. Handling inbound trickled candidates
8. Generating and handling the end-of-candidates indication
9. Handling ICE restarts

There is quite a bit of operational experience with the technique behind Trickle ICE, going back as far as 2005 (when the XMPP Jingle extension defined a "dribble mode" as specified in [[XEP-0176](#)]); this document incorporates feedback from those who have implemented and deployed the technique over the years.

## 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 for Interactive Connectivity Establishment in [[rfc5245bis](#)]. In addition, it defines the following terms:

**Full Trickle:** The typical mode of operation for Trickle ICE agents, in which the initial ICE description can include any number of candidates (even zero candidates) and does not need to include a full generation of candidates as in half trickle.

**Generation:** All of the candidates conveyed within an ICE session.

**Half Trickle:** A Trickle ICE mode of operation in which the initiator gathers a full generation of candidates strictly before creating and conveying the initial ICE description. Once conveyed, this candidate information can be processed by regular ICE agents, which do not require support for Trickle ICE. It also allows Trickle ICE capable responders to still gather candidates and perform connectivity checks in a non-blocking way, thus providing roughly "half" the advantages of Trickle ICE. The half trickle mechanism is mostly meant for use when the responder's support for Trickle ICE cannot be confirmed prior to conveying the initial ICE description.

**ICE Description:** Any attributes related to the ICE session (not candidates) required to configure an ICE agent. These include but are not limited to the username fragment, password, and other attributes.





**Trickled Candidates:** Candidates that a Trickle ICE agent conveys after conveying the initial ICE description or responding to the initial ICE description, but within the same ICE session.

Trickled candidates can be conveyed in parallel with candidate gathering and connectivity checks.

**Trickling:** The act of incrementally conveying trickled candidates.

**Empty Check List:** A check list that initially does not contain any candidate pairs because they will be incrementally added as they are trickled. (This scenario does not arise with a regular ICE agent, because all candidate pairs are known when the agent creates the check list set).

### **3. Determining Support for Trickle ICE**

To fully support Trickle ICE, using protocols SHOULD incorporate one of the following mechanisms so that implementations can determine whether Trickle ICE is supported:

1. Provide a capabilities discovery method so that agents can verify support of Trickle ICE prior to initiating a session (XMPP's Service Discovery [[XEP-0030](#)] is one such mechanism).
2. Make support for Trickle ICE mandatory so that user agents can assume support.

If a using protocol does not provide a method of determining ahead of time whether Trickle ICE is supported, agents can make use of the half trickle procedure described in [Section 16](#).

Prior to conveying the initial ICE description, agents that implement using protocols that support capabilities discovery can attempt to verify whether or not the remote party supports Trickle ICE. If an agent determines that the remote party does not support Trickle ICE, it MUST fall back to using regular ICE or abandon the entire session.

Even if a using protocol does not include a capabilities discovery method, a user agent can provide an indication within the ICE description that it supports Trickle ICE by communicating an ICE option of 'trickle'. This token MUST be provided either at the session level or, if at the data stream level, for every data stream (an agent MUST NOT specify Trickle ICE support for some data streams but not others). Note: The encoding of the 'trickle' ICE option, and the message(s) used to carry it to the peer, are protocol specific; for instance, the encoding for the Session Description Protocol (SDP) [[RFC4566](#)] is defined in [[I-D.ietf-mmusic-trickle-ice-sip](#)].



Dedicated discovery semantics and half trickle are needed only prior to initiation of an ICE session. After an ICE session is established and Trickle ICE support is confirmed for both parties, either agent can use full trickle for subsequent exchanges (see also [Section 15](#)).

#### **4. Generating the Initial ICE Description**

An ICE agent can start gathering candidates as soon as it has an indication that communication is imminent (e.g., a user interface cue or an explicit request to initiate a communication session). Unlike in regular ICE, in Trickle ICE implementations do not need to gather candidates in a blocking manner. Therefore, unless half trickle is being used, the user experience is improved if the initiating agent generates and transmits its initial ICE description as early as possible (thus enabling the remote party to start gathering and trickling candidates).

An initiator MAY include any mix of candidates when conveying the initial ICE description. This includes the possibility of conveying all the candidates the initiator plans to use (as in half trickle), conveying only a publicly-reachable IP address (e.g., a candidate at a data relay that is known to not be behind a firewall), or conveying no candidates at all (in which case the initiator can obtain the responder's initial candidate list sooner and the responder can begin candidate gathering more quickly).

For candidates included in the initial ICE description, the methods for calculating priorities and foundations, determining redundancy of candidates, and the like work just as in regular ICE [[rfc5245bis](#)].

#### **5. Handling the Initial ICE Description and Generating the Initial ICE Response**

When a responder receives the initial ICE description, it will first check if the ICE description or initiator indicates support for Trickle ICE as explained in [Section 3](#). If not, the responder MUST process the initial ICE description according to regular ICE procedures [[rfc5245bis](#)] (or, if no ICE support is detected at all, according to relevant processing rules for the using protocol, such as offer/answer processing rules [[RFC3264](#)]). However, if support for Trickle ICE is confirmed, a responder will automatically assume support for regular ICE as well.

If the initial ICE description indicates support for Trickle ICE, the responder will determine its role and start gathering and prioritizing candidates; while doing so, it will also respond by conveying an initial ICE response, so that both the initiator and the responder can form check lists and begin connectivity checks.



A responder can respond to the initial ICE description at any point while gathering candidates. The initial ICE response MAY contain any set of candidates, including all candidates or no candidates. (The benefit of including no candidates is to convey the initial ICE response as quickly as possible, so that both parties can consider the ICE session to be under active negotiation as soon as possible.)

As noted in [Section 3](#), in using protocols that use SDP the initial ICE response can indicate support for Trickle ICE by including a token of "trickle" in the ice-options attribute.

## **6. Handling the Initial ICE Response**

When processing the initial ICE response, the initiator follows regular ICE procedures to determine its role, after which it forms check lists ([Section 7](#)) and performs connectivity checks ([Section 8](#)).

## **7. Forming Check Lists**

According to regular ICE procedures [[rfc5245bis](#)], in order for candidate pairing to be possible and for redundant candidates to be pruned, the candidates would need to be provided in the initial ICE description and initial ICE response. By contrast, under Trickle ICE check lists can be empty until candidates are conveyed or received. Therefore a Trickle ICE agent handles check list formation and candidate pairing in a slightly different way than a regular ICE agent: the agent still forms the check lists, but it populates a given check list only after it actually has candidate pairs for that check list. Every check list is initially placed in the Running state, even if the check list is empty (this is consistent with Section 6.1.2.1 of [[rfc5245bis](#)]).

## **8. Performing Connectivity Checks**

As specified in [[rfc5245bis](#)], whenever timer Ta fires, only check lists in the Running state will be picked when scheduling connectivity checks for candidate pairs. Therefore, a Trickle ICE agent MUST keep each check list in the Running state as long as it expects candidate pairs to be incrementally added to the check list. After that, the check list state is set according to the procedures in [[rfc5245bis](#)].

Whenever timer Ta fires and an empty check list is picked, no action is performed for the list. Without waiting for timer Ta to expire again, the agent selects the next check list in the Running state, in accordance with Section 6.1.4.2 of [[rfc5245bis](#)].



Section 7.2.5.3.3 of [[rfc5245bis](#)] requires that agents update check lists and timer states upon completing a connectivity check transaction. During such an update, regular ICE agents would set the state of a check list to Failed if both of the following two conditions are satisfied:

- o all of the pairs in the check list are either in the Failed state or Succeeded state; and
- o there is not a pair in the valid list for each component of the data stream.

With Trickle ICE, the above situation would often occur when candidate gathering and trickling are still in progress, even though it is quite possible that future checks will succeed. For this reason, Trickle ICE agents add the following conditions to the above list:

- o all candidate gathering has completed and the agent is not expecting to discover any new local candidates; and
- o the remote agent has conveyed an end-of-candidates indication for that check list as described in [Section 13](#).

## **9. Gathering and Conveying Newly Gathered Local Candidates**

After Trickle ICE agents have conveyed initial ICE descriptions and initial ICE responses, they will most likely continue gathering new local candidates as STUN, TURN, and other non-host candidate gathering mechanisms begin to yield results. Whenever an agent discovers such a new candidate it will compute its priority, type, foundation, and component ID according to regular ICE procedures.

The new candidate is then checked for redundancy against the existing list of local candidates. If its transport address and base match those of an existing candidate, it will be considered redundant and will be ignored. This would often happen for server reflexive candidates that match the host addresses they were obtained from (e.g., when the latter are public IPv4 addresses). Contrary to regular ICE, Trickle ICE agents will consider the new candidate redundant regardless of its priority.

Next the agent "trickles" the newly discovered candidate(s) to the remote agent. The actual delivery of the new candidates is handled by a using protocol such as SIP or XMPP. Trickle ICE imposes no restrictions on the way this is done (e.g., some using protocols might choose not to trickle updates for server reflexive candidates and instead rely on the discovery of peer reflexive ones).





When candidates are trickled, the using protocol MUST deliver each candidate (and any end-of-candidates indication as described in [Section 13](#)) to the receiving Trickle ICE implementation exactly once and in the same order it was conveyed. If the using protocol provides any candidate retransmissions, they need to be hidden from the ICE implementation.

Also, candidate trickling needs to be correlated to a specific ICE session, so that if there is an ICE restart, any delayed updates for a previous session can be recognized as such and ignored by the receiving party. For example, using protocols that signal candidates via SDP might include a Username Fragment value in the corresponding a=candidate line, such as:

```
a=candidate:1 1 UDP 2130706431 2001:db8::1 5000 typ host ufrag 8hhY
```

Or, as another example, WebRTC implementations might include a Username Fragment in the JavaScript objects that represent candidates.

Note: The using protocol needs to provide a mechanism for both parties to indicate and agree on the ICE session in force (as identified by the Username Fragment and Password combination) so that they have a consistent view of which candidates are to be paired. This is especially important in the case of ICE restarts (see [Section 15](#)).

Note: A using protocol might prefer not to trickle server reflexive candidates to entities that are known to be publicly accessible and where sending a direct STUN binding request is likely to reach the destination faster than the trickle update that travels through the signaling path.

## **10. Pairing Newly Gathered Local Candidates**

As a Trickle ICE agent gathers local candidates, it needs to form candidate pairs; this works as described in the ICE specification [[rfc5245bis](#)], with the following provisos:

1. A Trickle ICE agent MUST NOT pair a local candidate until it has been trickled to the remote party.
2. Once the agent has conveyed the local candidate to the remote party, the agent checks if any remote candidates are currently known for this same stream and component. If not, the agent



merely adds the new candidate to the list of local candidates (without pairing it).

3. Otherwise, if the agent has already learned of one or more remote candidates for this stream and component, it attempts to pair the new local candidate as described in the ICE specification [[rfc5245bis](#)].
4. If a newly formed pair has a local candidate whose type is server reflexive, the agent MUST replace the local candidate with its base before completing the relevant redundancy tests.
5. The agent prunes redundant pairs by following the rules in Section 6.1.2.4 of [[rfc5245bis](#)], but checks existing pairs only if they have a state of Waiting or Frozen; this avoids removal of pairs for which connectivity checks are in flight (a state of In-Progress) or for which connectivity checks have already yielded a definitive result (a state of Succeeded or Failed).
6. If after the relevant redundancy tests the check list where the pair is to be added already contains the maximum number of candidate pairs (100 by default as per [[rfc5245bis](#)]), the agent SHOULD discard any pairs in the Failed state to make room for the new pair. If there are no such pairs, the agent SHOULD discard a pair with a lower priority than the new pair in order to make room for the new pair, until the number of pairs is equal to the maximum number of pairs. This processing is consistent with Section 6.1.2.5 of [[rfc5245bis](#)].

## **11. Receiving Trickled Candidates**

At any time during an ICE session, a Trickle ICE agent might receive new candidates from the remote agent, from which it will attempt to form a candidate pair; this works as described in the ICE specification [[rfc5245bis](#)], with the following provisos:

1. The agent checks if any local candidates are currently known for this same stream and component. If not, the agent merely adds the new candidate to the list of remote candidates (without pairing it).
2. Otherwise, if the agent has already gathered one or more local candidates for this stream and component, it attempts to pair the new remote candidate as described in the ICE specification [[rfc5245bis](#)].



3. If a newly formed pair has a local candidate whose type is server reflexive, the agent MUST replace the local candidate with its base before completing the redundancy check in the next step.
4. The agent prunes redundant pairs as described below, but checks existing pairs only if they have a state of Waiting or Frozen; this avoids removal of pairs for which connectivity checks are in flight (a state of In-Progress) or for which connectivity checks have already yielded a definitive result (a state of Succeeded or Failed).
  - A. If the agent finds a redundancy between two pairs and one of those pairs contains a newly received remote candidate whose type is peer reflexive, the agent SHOULD discard the pair containing that candidate, set the priority of the existing pair to the priority of the discarded pair, and re-sort the check list. (This policy helps to eliminate problems with remote peer reflexive candidates for which a STUN binding request is received before signaling of the candidate is trickled to the receiving agent, such as a different view of pair priorities between the local agent and the remote agent, since the same candidate could be perceived as peer reflexive by one agent and as server reflexive by the other agent.)
  - B. The agent then applies the rules defined in Section 6.1.2.4 of [[rfc5245bis](#)].
5. If after the relevant redundancy tests the check list where the pair is to be added already contains the maximum number of candidate pairs (100 by default as per [[rfc5245bis](#)]), the agent SHOULD discard any pairs in the Failed state to make room for the new pair. If there are no such pairs, the agent SHOULD discard a pair with a lower priority than the new pair in order to make room for the new pair, until the number of pairs is equal to the maximum number of pairs. This processing is consistent with Section 6.1.2.5 of [[rfc5245bis](#)].

## **12. Inserting Trickled Candidate Pairs into a Check List**

After a local agent has trickled a candidate and formed a candidate pair from that local candidate ([Section 9](#)), or after a remote agent has received a trickled candidate and formed a candidate pair from that remote candidate ([Section 11](#)), a Trickle ICE agent adds the new candidate pair to a check list as defined in this section.

As an aid to understanding the procedures defined in this section, consider the following tabular representation of all check lists in



an agent (note that initially for one of the foundations, i.e., f5, there are no candidate pairs):

	f1	f2	f3	f4	f5
s1 (Audio.RTP)	F	F	F		
s2 (Audio.RTCP)	F	F	F	F	
s3 (Video.RTP)	F				
s4 (Video.RTCP)	F				

Figure 2: Example of Check List State

Each row in the table represents a component for a given data stream (e.g., s1 and s2 might be the RTP and RTCP components for audio) and thus a single check list in the check list set. Each column represents one foundation. Each cell represents one candidate pair. In the tables shown in this section, "F" stands for "frozen", "W" stands for "waiting", and "S" stands for "succeeded"; in addition, "^^" is used to notate newly-added candidate pairs.

When an agent commences ICE processing, in accordance with Section 6.1.2.6 of [\[rfc5245bis\]](#), for each foundation it will unfreeze the pair with the lowest component ID and, if the component IDs are equal, with the highest priority (this is the topmost candidate pair in every column). This initial state is shown in the following table.





	f1	f2	f3	f4	f5
s1 (Audio.RTP)	W	W	W		
s2 (Audio.RTCP)	F	F	F	W	
s3 (Video.RTP)	F				
s4 (Video.RTCP)	F				

Figure 3: Initial Check List State

Then, as the checks proceed (see Section 7.2.5.4 of [[rfc5245bis](#)]), for each pair that enters the Succeeded state (denoted here by "S"), the agent will unfreeze all pairs for all data streams with the same foundation (e.g., if the pair in column 1, row 1 succeeds then the agent will unfreeze the pair in column 1, rows 2, 3, and 4).

	f1	f2	f3	f4	f5
s1 (Audio.RTP)	S	W	W		
s2 (Audio.RTCP)	W	F	F	W	
s3 (Video.RTP)	W				
s4 (Video.RTCP)	W				

Figure 4: Check List State with Succeeded Candidate Pair

Trickle ICE preserves all of these rules as they apply to "static" check list sets. This implies that if a Trickle ICE agent were to begin connectivity checks with all of its pairs already present, the way that pair states change is indistinguishable from that of a regular ICE agent.

Of course, the major difference with Trickle ICE is that check list sets can be dynamically updated because candidates can arrive after connectivity checks have started. When this happens, an agent sets the state of the newly formed pair as described below.



Rule 1: If the newly formed pair has the lowest component ID and, if the component IDs are equal, the highest priority of any candidate pair for this foundation (i.e., if it is the topmost pair in the column), set the state to Waiting. For example, this would be the case if the newly formed pair were placed in column 5, row 1. This rule is consistent with Section 6.1.2.6 of [[rfc5245bis](#)].

```

+-----+-----+-----+-----+-----+
|           | f1  | f2  | f3  | f4  | f5  |
+-----+-----+-----+-----+-----+
| s1 (Audio.RTP) | S   | W   | W   |     | ^W^ |
+-----+-----+-----+-----+-----+
| s2 (Audio.RTCP) | W   | F   | F   | W   |     |
+-----+-----+-----+-----+-----+
| s3 (Video.RTP)  | W   |     |     |     |     |
+-----+-----+-----+-----+-----+
| s4 (Video.RTCP) | W   |     |     |     |     |
+-----+-----+-----+-----+-----+
    
```

Figure 5: Check List State with Newly Formed Pair, Rule 1

Rule 2: If there is at least one pair in the Succeeded state for this foundation, set the state to Waiting. For example, this would be the case if the pair in column 5, row 1 succeeded and the newly formed pair were placed in column 5, row 2. This rule is consistent with Section 7.2.5.3.3 of [[rfc5245bis](#)].

```

+-----+-----+-----+-----+-----+
|           | f1  | f2  | f3  | f4  | f5  |
+-----+-----+-----+-----+-----+
| s1 (Audio.RTP) | S   | W   | W   |     | S   |
+-----+-----+-----+-----+-----+
| s2 (Audio.RTCP) | W   | F   | F   | W   | ^W^ |
+-----+-----+-----+-----+-----+
| s3 (Video.RTP)  | W   |     |     |     |     |
+-----+-----+-----+-----+-----+
| s4 (Video.RTCP) | W   |     |     |     |     |
+-----+-----+-----+-----+-----+
    
```

Figure 6: Check List State with Newly Formed Pair, Rule 2

Rule 3: In all other cases, set the state to Frozen. For example, this would be the case if the newly formed pair were placed in column 3, row 3.



	f1	f2	f3	f4	f5
s1 (Audio.RTP)	S	W	W		S
s2 (Audio.RTCP)	W	F	F	W	W
s3 (Video.RTP)	W		^F^		
s4 (Video.RTCP)	W				

Figure 7: Check List State with Newly Formed Pair, Rule 3

### 13. Generating an End-of-Candidates Indication

Once all candidate gathering is completed or expires for an ICE session associated with a specific data stream, the agent will generate an "end-of-candidates" indication for that session and convey it to the remote agent via the signaling channel. Although the exact form of the indication depends on the using protocol, the indication MUST specify the generation (Username Fragment and Password combination) so that an agent can correlate the end-of-candidates indication with a particular ICE session. The indication can be conveyed in the following ways:

- o As part of an initiation request (which would typically be the case with the initial ICE description for half trickle)
- o Along with the last candidate an agent can send for a stream
- o As a standalone notification (e.g., after STUN Binding requests or TURN Allocate requests to a server time out and the agent is no longer actively gathering candidates)

Conveying an end-of-candidates indication in a timely manner is important in order to avoid ambiguities and speed up the conclusion of ICE processing. In particular:

- o A controlled Trickle ICE agent SHOULD convey an end-of-candidates indication after it has completed gathering for a data stream, unless ICE processing terminates before the agent has had a chance to complete gathering.
- o A controlling agent MAY conclude ICE processing prior to conveying end-of-candidates indications for all streams. However, it is RECOMMENDED for a controlling agent to convey end-of-candidates



indications whenever possible for the sake of consistency and to keep middleboxes and controlled agents up-to-date on the state of ICE processing.

When conveying an end-of-candidates indication during trickling (rather than as a part of the initial ICE description or a response thereto), it is the responsibility of the using protocol to define methods for associating the indication with one or more specific data streams.

An agent MAY also choose to generate an end-of-candidates indication before candidate gathering has actually completed, if the agent determines that gathering has continued for more than an acceptable period of time. However, an agent MUST NOT convey any more candidates after it has conveyed an end-of-candidates indication.

When performing half trickle, an agent SHOULD convey an end-of-candidates indication together with its initial ICE description unless it is planning to potentially trickle additional candidates (e.g., in case the remote party turns out to support Trickle ICE).

After an agent conveys the end-of-candidates indication, it will update the state of the corresponding check list as explained in [Section 8](#). Past that point, an agent MUST NOT trickle any new candidates within this ICE session. Therefore, adding new candidates to the negotiation is possible only through an ICE restart (see [Section 15](#)).

This specification does not override regular ICE semantics for concluding ICE processing. Therefore, even if end-of-candidates indications are conveyed, an agent will still need to go through pair nomination. Also, if pairs have been nominated for components and data streams, ICE processing MAY still conclude even if end-of-candidates indications have not been received for all streams. In all cases, an agent MUST NOT trickle any new candidates within an ICE session after nomination of a candidate pair as described in Section 8.1.1 of [[rfc5245bis](#)].

#### **14. Receiving an End-of-Candidates Indication**

Receiving an end-of-candidates indication enables an agent to update check list states and, in case valid pairs do not exist for every component in every data stream, determine that ICE processing has failed. It also enables an agent to speed up the conclusion of ICE processing when a candidate pair has been validated but it involves the use of lower-preference transports such as TURN. In such situations, an implementation MAY choose to wait and see if higher-priority candidates are received; in this case the end-of-candidates





indication provides a notification that such candidates are not forthcoming.

When an agent receives an end-of-candidates indication for a specific data stream, it will update the state of the relevant check list as per [Section 8](#) (which might lead to some check lists being marked as Failed). If the check list is still in the Running state after the update, the agent will persist the fact that an end-of-candidates indication has been received and take it into account in future updates to the check list.

After an agent has received an end-of-candidates indication, it MUST ignore any newly received candidates for that data stream or data session.

## **15. Subsequent Exchanges and ICE Restarts**

Before conveying an end-of-candidates indication, either agent MAY convey subsequent candidate information at any time allowed by the using protocol. When this happens, agents will use [[rfc5245bis](#)] semantics (e.g., checking of the Username Fragment and Password combination) to determine whether or not the new candidate information requires an ICE restart.

If an ICE restart occurs, the agents can assume that Trickle ICE is still supported if support was determined previously, and thus can engage in Trickle ICE behavior as they would in an initial exchange of ICE descriptions where support was determined through a capabilities discovery method.

## **16. Half Trickle**

In half trickle, the initiator conveys the initial ICE description with a usable but not necessarily full generation of candidates. This ensures that the ICE description can be processed by a regular ICE responder and is mostly meant for use in cases where support for Trickle ICE cannot be confirmed prior to conveying the initial ICE description. The initial ICE description indicates support for Trickle ICE, so that the responder can respond with something less than a full generation of candidates and then trickle the rest. The initial ICE description for half trickle can contain an end-of-candidates indication, although this is not mandatory because if trickle support is confirmed then the initiator can choose to trickle additional candidates before it conveys an end-of-candidates indication.

The half trickle mechanism can be used in cases where there is no way for an agent to verify in advance whether a remote party supports



Trickle ICE. Because the initial ICE description contain a full generation of candidates, it can thus be handled by a regular ICE agent, while still allowing a Trickle ICE agent to use the optimization defined in this specification. This prevents negotiation from failing in the former case while still giving roughly half the Trickle ICE benefits in the latter.

Use of half trickle is only necessary during an initial exchange of ICE descriptions. After both parties have received an ICE description from their peer, they can each reliably determine Trickle ICE support and use it for all subsequent exchanges (see [Section 15](#)).

In some instances, using half trickle might bring more than just half the improvement in terms of user experience. This can happen when an agent starts gathering candidates upon user interface cues that the user will soon be initiating an interaction, such as activity on a keypad or the phone going off hook. This would mean that some or all of the candidate gathering could be completed before the agent actually needs to convey the candidate information. Because the responder will be able to trickle candidates, both agents will be able to start connectivity checks and complete ICE processing earlier than with regular ICE and potentially even as early as with full trickle.

However, such anticipation is not always possible. For example, a multipurpose user agent or a WebRTC web page where communication is a non-central feature (e.g., calling a support line in case of a problem with the main features) would not necessarily have a way of distinguishing between call intentions and other user activity. In such cases, using full trickle is most likely to result in an ideal user experience. Even so, using half trickle would be an improvement over regular ICE because it would result in a better experience for responders.

## **17. Preserving Candidate Order while Trickling**

One important aspect of regular ICE is that connectivity checks for a specific foundation and component are attempted simultaneously by both agents, so that any firewalls or NATs fronting the agents would whitelist both endpoints and allow all except for the first ("suicide") packets to go through. This is also important to unfreezing candidates at the right time. While not crucial, preserving this behavior in Trickle ICE is likely to improve ICE performance.

To achieve this, when trickling candidates, agents SHOULD respect the order of components as reflected by their component IDs; that is, candidates for a given component SHOULD NOT be conveyed prior to



candidates for a component with a lower ID number within the same foundation. In addition, candidates SHOULD be paired, following the procedures in [Section 12](#), in the same order they are conveyed.

For example, the following SDP description contains two components (RTP and RTCP) and two foundations (host and server reflexive):

```
v=0
o=jdoe 2890844526 2890842807 IN IP4 10.0.1.1
s=
c=IN IP4 10.0.1.1
t=0 0
a=ice-pwd:asd88fgpdd777uzjYhagZg
a=ice-ufrag:8hhY
m=audio 5000 RTP/AVP 0
a=rtpmap:0 PCMU/8000
a=candidate:1 1 UDP 2130706431 10.0.1.1 5000 typ host
a=candidate:1 2 UDP 2130706431 10.0.1.1 5001 typ host
a=candidate:2 1 UDP 1694498815 192.0.2.3 5000 typ srflx
  raddr 10.0.1.1 rport 8998
a=candidate:2 2 UDP 1694498815 192.0.2.3 5001 typ srflx
  raddr 10.0.1.1 rport 8998
```

For this candidate information the RTCP host candidate would not be conveyed prior to the RTP host candidate. Similarly the RTP server reflexive candidate would be conveyed together with or prior to the RTCP server reflexive candidate.

## **18. Requirements for Using Protocols**

In order to fully enable the use of Trickle ICE, this specification defines the following requirements for using protocols.

- o A using protocol SHOULD provide a way for parties to advertise and discover support for Trickle ICE before an ICE session begins (see [Section 3](#)).
- o A using protocol MUST provide methods for incrementally conveying (i.e., "trickling") additional candidates after conveying the initial ICE description (see [Section 9](#)).
- o A using protocol MUST deliver each trickled candidate or end-of-candidates indication exactly once and in the same order it was conveyed (see [Section 9](#)).



- o A using protocol MUST provide a mechanism for both parties to indicate and agree on the ICE session in force (see [Section 9](#)).
- o A using protocol MUST provide a way for parties to communicate the end-of-candidates indication, which MUST specify the particular ICE session to which the indication applies (see [Section 13](#)).

## **19. IANA Considerations**

IANA is requested to register the following ICE option in the "ICE Options" sub-registry of the "Interactive Connectivity Establishment (ICE) registry", following the procedures defined in [[RFC6336](#)].

ICE Option: trickle

Contact: IESG, [iesg@ietf.org](mailto:iesg@ietf.org)

Change control: IESG

Description: An ICE option of "trickle" indicates support for incremental communication of ICE candidates.

Reference: RFC XXXX

## **20. Security Considerations**

This specification inherits most of its semantics from [[rfc5245bis](#)] and as a result all security considerations described there apply to Trickle ICE.

If the privacy implications of revealing host addresses on an endpoint device are a concern (see for example the discussion in [[I-D.ietf-rtcweb-ip-handling](#)] and in Section 19 of [[rfc5245bis](#)]), agents can generate ICE descriptions that contain no candidates and then only trickle candidates that do not reveal host addresses (e.g., relayed candidates).

## **21. Acknowledgements**

The authors would like to thank Bernard Aboba, Flemming Andreasen, Rajmohan Banavi, Taylor Brandstetter, Philipp Hancke, Christer Holmberg, Ari Keranen, Paul Kyzivat, Jonathan Lennox, Enrico Marocco, Pal Martinsen, Nils Ohlmeier, Thomas Stach, Peter Thatcher, Martin Thomson, Brandon Williams, and Dale Worley for their reviews and suggestions on improving this document. Sarah Banks, Roni Even, and David Mandelberg completed opsdire, genart, and security reviews, respectively. Thanks also to Ari Keranen and Peter Thatcher in their





role as chairs, and Ben Campbell in his role as responsible Area Director.

## 22. References

### 22.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.

[rfc5245bis]  
Keranen, A., Holmberg, C., and J. Rosenberg, "Interactive Connectivity Establishment (ICE): A Protocol for Network Address Translator (NAT) Traversal", [draft-ietf-ice-rfc5245bis-20](#) (work in progress), March 2018.

### 22.2. Informative References

[I-D.ietf-mmusic-trickle-ice-sip]  
Ivov, E., Stach, T., Marocco, E., and C. Holmberg, "A Session Initiation Protocol (SIP) usage for Trickle ICE", [draft-ietf-mmusic-trickle-ice-sip-14](#) (work in progress), February 2018.

[I-D.ietf-rtcweb-ip-handling]  
Uberti, J. and G. Shieh, "WebRTC IP Address Handling Requirements", [draft-ietf-rtcweb-ip-handling-06](#) (work in progress), March 2018.

[RFC1918] Rekhter, Y., Moskowitz, B., Karrenberg, D., de Groot, G., and E. Lear, "Address Allocation for Private Internets", [BCP 5](#), [RFC 1918](#), DOI 10.17487/RFC1918, February 1996, <<https://www.rfc-editor.org/info/rfc1918>>.

[RFC3261] Rosenberg, J., Schulzrinne, H., Camarillo, G., Johnston, A., Peterson, J., Sparks, R., Handley, M., and E. Schooler, "SIP: Session Initiation Protocol", [RFC 3261](#), DOI 10.17487/RFC3261, June 2002, <<https://www.rfc-editor.org/info/rfc3261>>.

[RFC3264] Rosenberg, J. and H. Schulzrinne, "An Offer/Answer Model with Session Description Protocol (SDP)", [RFC 3264](#), DOI 10.17487/RFC3264, June 2002, <<https://www.rfc-editor.org/info/rfc3264>>.



- [RFC4566] Handley, M., Jacobson, V., and C. Perkins, "SDP: Session Description Protocol", [RFC 4566](#), DOI 10.17487/RFC4566, July 2006, <<https://www.rfc-editor.org/info/rfc4566>>.
- [RFC4787] Audet, F., Ed. and C. Jennings, "Network Address Translation (NAT) Behavioral Requirements for Unicast UDP", [BCP 127](#), [RFC 4787](#), DOI 10.17487/RFC4787, January 2007, <<https://www.rfc-editor.org/info/rfc4787>>.
- [RFC5389] Rosenberg, J., Mahy, R., Matthews, P., and D. Wing, "Session Traversal Utilities for NAT (STUN)", [RFC 5389](#), DOI 10.17487/RFC5389, October 2008, <<https://www.rfc-editor.org/info/rfc5389>>.
- [RFC5766] Mahy, R., Matthews, P., and J. Rosenberg, "Traversal Using Relays around NAT (TURN): Relay Extensions to Session Traversal Utilities for NAT (STUN)", [RFC 5766](#), DOI 10.17487/RFC5766, April 2010, <<https://www.rfc-editor.org/info/rfc5766>>.
- [RFC6120] Saint-Andre, P., "Extensible Messaging and Presence Protocol (XMPP): Core", [RFC 6120](#), DOI 10.17487/RFC6120, March 2011, <<https://www.rfc-editor.org/info/rfc6120>>.
- [RFC6336] Westerlund, M. and C. Perkins, "IANA Registry for Interactive Connectivity Establishment (ICE) Options", [RFC 6336](#), DOI 10.17487/RFC6336, July 2011, <<https://www.rfc-editor.org/info/rfc6336>>.
- [XEP-0030] Hildebrand, J., Millard, P., Eatmon, R., and P. Saint-Andre, "XEP-0030: Service Discovery", XEP XEP-0030, June 2008.
- [XEP-0176] Beda, J., Ludwig, S., Saint-Andre, P., Hildebrand, J., Egan, S., and R. McQueen, "XEP-0176: Jingle ICE-UDP Transport Method", XEP XEP-0176, June 2009.

## [Appendix A](#). Interaction with Regular ICE

The ICE protocol was designed to be flexible enough to work in and adapt to as many network environments as possible. Despite that flexibility, ICE as specified in [[rfc5245bis](#)] does not by itself support trickle ICE. This section describes how trickling of candidates interacts with ICE.



[rfc5245bis] describes the conditions required to update check lists and timer states while an ICE agent is in the Running state. These conditions are verified upon transaction completion and one of them stipulates that:

If there is not a pair in the valid list for each component of the data stream, the state of the check list is set to Failed.

This could be a problem and cause ICE processing to fail prematurely in a number of scenarios. Consider the following case:

1. Alice and Bob are both located in different networks with Network Address Translation (NAT). Alice and Bob themselves have different address but both networks use the same private internet block (e.g., the "20-bit block" 172.16/12 specified in [\[RFC1918\]](#)).
2. Alice conveys to Bob the candidate 172.16.0.1 which also happens to correspond to an existing host on Bob's network.
3. Bob creates a check list consisting solely of 172.16.0.1 and starts checks.
4. These checks reach the host at 172.16.0.1 in Bob's network, which responds with an ICMP "port unreachable" error; per [\[rfc5245bis\]](#) Bob marks the transaction as Failed.

At this point the check list only contains Failed candidates and the valid list is empty. This causes the data stream and potentially all ICE processing to fail, even though if Trickle ICE agents could subsequently convey candidates that would cause previously empty check lists to become non-empty.

A similar race condition would occur if the initial ICE description from Alice contain only candidates that can be determined as unreachable from any of the candidates that Bob has gathered (e.g., this would be the case if Bob's candidates only contain IPv4 addresses and the first candidate that he receives from Alice is an IPv6 one).

Another potential problem could arise when a non-trickle ICE implementation initiates an interaction with a Trickle ICE implementation. Consider the following case:

1. Alice's client has a non-Trickle ICE implementation.
2. Bob's client has support for Trickle ICE.



3. Alice and Bob are behind NATs with address-dependent filtering [[RFC4787](#)].
4. Bob has two STUN servers but one of them is currently unreachable.

After Bob's agent receives Alice's initial ICE description it would immediately start connectivity checks. It would also start gathering candidates, which would take a long time because of the unreachable STUN server. By the time Bob's answer is ready and conveyed to Alice, Bob's connectivity checks might have failed: until Alice gets Bob's answer, she won't be able to start connectivity checks and punch holes in her NAT. The NAT would hence be filtering Bob's checks as originating from an unknown endpoint.

#### **[Appendix B](#). Interaction with ICE Lite**

The behavior of ICE lite agents that are capable of Trickle ICE does not require any particular rules other than those already defined in this specification and [[rfc5245bis](#)]. This section is hence provided only for informational purposes.

An ICE lite agent would generate candidate information as per [[rfc5245bis](#)] and would indicate support for Trickle ICE. Given that the candidate information will contain a full generation of candidates, it would also be accompanied by an end-of-candidates indication.

When performing full trickle, a full ICE implementation could convey the initial ICE description or response thereto with no candidates. After receiving a response that identifies the remote agent as an ICE lite implementation, the initiator can choose to not trickle any additional candidates. The same is also true in the case when the ICE lite agent initiates the interaction and the full ICE agent is the responder. In these cases the connectivity checks would be enough for the ICE lite implementation to discover all potentially useful candidates as peer reflexive. The following example illustrates one such ICE session using SDP syntax:





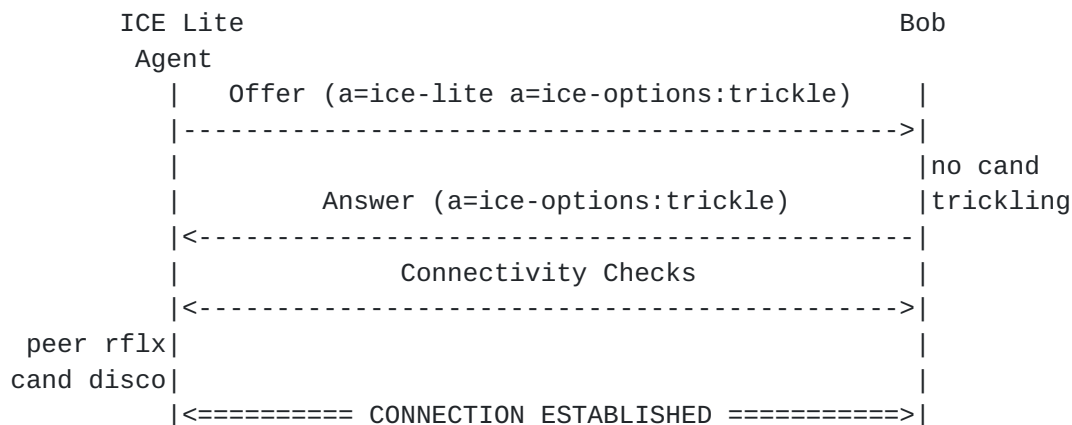


Figure 8: Example

In addition to reducing signaling traffic this approach also removes the need to discover STUN bindings or make TURN allocations, which can considerably lighten ICE processing.

**Appendix C. Changes from Earlier Versions**

Note to the RFC Editor: please remove this section prior to publication as an RFC.

**C.1. Changes from [draft-ietf-ice-trickle-20](#)**

- o Slight corrections to handling of peer reflexive candidates.
- o Wordsmithing in a few sections.

**C.2. Changes from [draft-ietf-ice-trickle-19](#)**

- o Further clarified handling of remote peer reflexive candidates.
- o To improve readability, renamed and restructured some sections and subsections, and modified some wording.

**C.3. Changes from [draft-ietf-ice-trickle-18](#)**

- o Cleaned up pairing and redundancy checking rules for newly discovered candidates per IESG feedback and WG discussion.
- o Improved wording in half trickle section.
- o Changed "not more than once" to "exactly once".



- o Changed NAT examples back to IPv4.

#### **C.4. Changes from [draft-ietf-ice-trickle-17](#)**

- o Simplified the rules for inserting a new pair in a check list.
- o Clarified it is not allowed to nominate a candidate pair after a pair has already been nominated (a.k.a. renomination or continuous nomination).
- o Removed some text that referenced older versions of rfc5245bis.
- o Removed some text that duplicated concepts and procedures specified in rfc5245bis.
- o Removed the ill-defined concept of stream order.
- o Shortened the introduction.

#### **C.5. Changes from [draft-ietf-ice-trickle-16](#)**

- o Made "ufrag" terminology consistent with 5245bis.
- o Applied in-order delivery rule to end-of-candidates indication.

#### **C.6. Changes from [draft-ietf-ice-trickle-15](#)**

- o Adjustments to address AD review feedback.

#### **C.7. Changes from [draft-ietf-ice-trickle-14](#)**

- o Minor modifications to track changes to ICE core.

#### **C.8. Changes from [draft-ietf-ice-trickle-13](#)**

- o Removed independent monitoring of check list "states" of frozen or active, since this is handled by placing a check list in the Running state defined in ICE core.

#### **C.9. Changes from [draft-ietf-ice-trickle-12](#)**

- o Specified that the end-of-candidates indication must include the generation (ufrag/pwd) to enable association with a particular ICE session.
- o Further editorial fixes to address WGLC feedback.



**C.10.** Changes from [draft-ietf-ice-trickle-11](#)

- o Editorial and terminological fixes to address WGLC feedback.

**C.11.** Changes from [draft-ietf-ice-trickle-10](#)

- o Minor editorial fixes.

**C.12.** Changes from [draft-ietf-ice-trickle-09](#)

- o Removed immediate unfreeze upon Fail.
- o Specified MUST NOT regarding ice-options.
- o Changed terminology regarding initial ICE parameters to avoid implementer confusion.

**C.13.** Changes from [draft-ietf-ice-trickle-08](#)

- o Reinstated text about in-order processing of messages as a requirement for signaling protocols.
- o Added IANA registration template for ICE option.
- o Corrected Case 3 rule in [Section 8.1.1](#) to ensure consistency with regular ICE rules.
- o Added tabular representations to [Section 8.1.1](#) in order to illustrate the new pair rules.

**C.14.** Changes from [draft-ietf-ice-trickle-07](#)

- o Changed "ICE description" to "candidate information" for consistency with 5245bis.

**C.15.** Changes from [draft-ietf-ice-trickle-06](#)

- o Addressed editorial feedback from chairs' review.
- o Clarified terminology regarding generations.

**C.16.** Changes from [draft-ietf-ice-trickle-05](#)

- o Rewrote the text on inserting a new pair into a check list.



**C.17.** Changes from [draft-ietf-ice-trickle-04](#)

- o Removed dependency on SDP and offer/answer model.
- o Removed mentions of aggressive nomination, since it is deprecated in 5245bis.
- o Added section on requirements for signaling protocols.
- o Clarified terminology.
- o Addressed various WG feedback.

**C.18.** Changes from [draft-ietf-ice-trickle-03](#)

- o Provided more detailed description of unfreezing behavior, specifically how to replace pre-existing peer-reflexive candidates with higher-priority ones received via trickling.

**C.19.** Changes from [draft-ietf-ice-trickle-02](#)

- o Adjusted unfreezing behavior when there are disparate foundations.

**C.20.** Changes from [draft-ietf-ice-trickle-01](#)

- o Changed examples to use IPV6.

**C.21.** Changes from [draft-ietf-ice-trickle-00](#)

- o Removed dependency on SDP (which is to be provided in a separate specification).
- o Clarified text about the fact that a check list can be empty if no candidates have been sent or received yet.
- o Clarified wording about check list states so as not to define new states for "Active" and "Frozen" because those states are not defined for check lists (only for candidate pairs) in ICE core.
- o Removed open issues list because it was out of date.
- o Completed a thorough copy edit.

**C.22.** Changes from [draft-mmusic-trickle-ice-02](#)

- o Addressed feedback from Rajmohan Banavi and Brandon Williams.





- o Clarified text about determining support and about how to proceed if it can be determined that the answering agent does not support Trickle ICE.
- o Clarified text about check list and timer updates.
- o Clarified when it is appropriate to use half trickle or to send no candidates in an offer or answer.
- o Updated the list of open issues.

#### **C.23. Changes from [draft-ivov-01](#) and [draft-mmusic-00](#)**

- o Added a requirement to trickle candidates by order of components to avoid deadlocks in the unfreezing algorithm.
- o Added an informative note on peer-reflexive candidates explaining that nothing changes for them semantically but they do become a more likely occurrence for Trickle ICE.
- o Limit the number of pairs to 100 to comply with 5245.
- o Added clarifications on the non-importance of how newly discovered candidates are trickled/sent to the remote party or if this is done at all.
- o Added transport expectations for trickled candidates as per Dale Worley's recommendation.

#### **C.24. Changes from [draft-ivov-00](#)**

- o Specified that end-of-candidates is a media level attribute which can of course appear as session level, which is equivalent to having it appear in all m-lines. Also made end-of-candidates optional for cases such as aggressive nomination for controlled agents.
- o Added an example for ICE lite and Trickle ICE to illustrate how, when talking to an ICE lite agent doesn't need to send or even discover any candidates.
- o Added an example for ICE lite and Trickle ICE to illustrate how, when talking to an ICE lite agent doesn't need to send or even discover any candidates.
- o Added wording that explicitly states ICE lite agents have to be prepared to receive no candidates over signaling and that they



should not freak out if this happens. (Closed the corresponding open issue).

- o It is now mandatory to use MID when trickling candidates and using m-line indexes is no longer allowed.
- o Replaced use of 0.0.0.0 to IP6 :: in order to avoid potential issues with [RFC2543](#) SDP libraries that interpret 0.0.0.0 as an on-hold operation. Also changed the port number here from 1 to 9 since it already has a more appropriate meaning. (Port change suggested by Jonathan Lennox).
- o Closed the Open Issue about use about what to do with cands received after end-of-cands. Solution: ignore, do an ICE restart if you want to add something.
- o Added more terminology, including trickling, trickled candidates, half trickle, full trickle,
- o Added a reference to the SIP usage for Trickle ICE as requested at the Boston interim.

#### **C.25. Changes from [draft-rescorla-01](#)**

- o Brought back explicit use of Offer/Answer. There are no more attempts to try to do this in an O/A independent way. Also removed the use of ICE Descriptions.
- o Added SDP specification for trickled candidates, the trickle option and 0.0.0.0 addresses in m-lines, and end-of-candidates.
- o Support and Discovery. Changed that section to be less abstract. As discussed in IETF85, the draft now says implementations and usages need to either determine support in advance and directly use trickle, or do half trickle. Removed suggestion about use of discovery in SIP or about letting implementing protocols do what they want.
- o Defined Half Trickle. Added a section that says how it works. Mentioned that it only needs to happen in the first o/a (not necessary in updates), and added Jonathan's comment about how it could, in some cases, offer more than half the improvement if you can pre-gather part or all of your candidates before the user actually presses the call button.
- o Added a short section about subsequent offer/answer exchanges.



- o Added a short section about interactions with ICE Lite implementations.
- o Added two new entries to the open issues section.

#### **C.26. Changes from [draft-rescorla-00](#)**

- o Relaxed requirements about verifying support following a discussion on MMUSIC.
- o Introduced ICE descriptions in order to remove ambiguous use of 3264 language and inappropriate references to offers and answers.
- o Removed inappropriate assumption of adoption by RTCWEB pointed out by Martin Thomson.

#### Authors' Addresses

Emil Ivov  
Atlassian  
303 Colorado Street, #1600  
Austin, TX 78701  
USA

Phone: +1-512-640-3000  
Email: [eivov@atlassian.com](mailto:eivov@atlassian.com)

Eric Rescorla  
RTFM, Inc.  
2064 Edgewood Drive  
Palo Alto, CA 94303  
USA

Phone: +1 650 678 2350  
Email: [ekr@rtfm.com](mailto:ekr@rtfm.com)

Justin Uberti  
Google  
747 6th St S  
Kirkland, WA 98033  
USA

Phone: +1 857 288 8888  
Email: [justin@uberti.name](mailto:justin@uberti.name)



Peter Saint-Andre  
Mozilla  
P.O. Box 787  
Parker, CO 80134  
USA

Phone: +1 720 256 6756

Email: [stpeter@mozilla.com](mailto:stpeter@mozilla.com)

URI: <https://www.mozilla.com/>