Building a neighbourhood with Dispersy

Boudewijn Schoon

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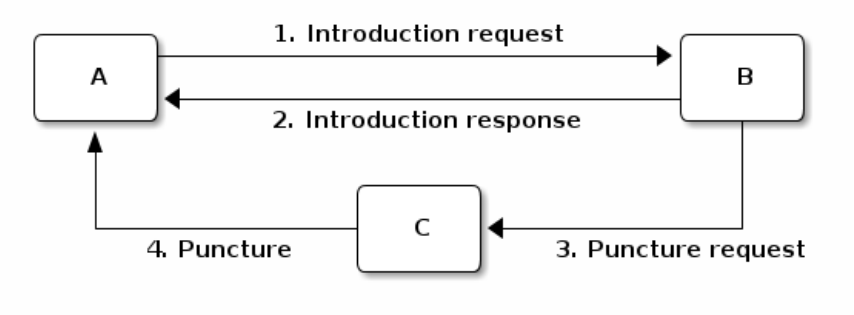
Contents

1 Concept

The *Dispersy walker* is one of the core components that make up the Dispersy library. We designed the walker to provide NAT resilient peer discovery, allowing Dispersy to build a semi-random neighbourhood within common real world environments.

The walker works by periodically asking known neighbours to introduce them to a new neighbour, we call this *taking a step*. Performing multiple steps allows peers to build their own neighbourhood, we call this *walking*.



The figure above shows a schematic representation of peer A performing a single step towards peer B and peer B introduces it to peer C. Each step contains the following phases:

phase 1. peer A chooses a known peer B from its neighbourhood and sends it an introduction-request;

phase 2. Peer B chooses a known peer C from its neighbourhood and sends peer A an introduction-response containing the address of peer C;

phase 3. peer B sends peer C a puncture-request containing the address of peer A;

phase 4. peer C sends peer A a puncture message to puncture a hole in its own NAT.

The remainder of this document will explain the walker design in detail and gives the reasoning behind design choices.

- Section 2 explains how we handle addresses and identities using candidates;
- Section 3 explains how peer A chooses from its neighbourhood;
- Section 4 explains how peer B chooses from its neighbourhood;
- Section 5 explains how peer B may influence peer A's LAN and WAN address;
- Section 6 explains how peer A estimates its own WAN address;
- Section 8 explains public key exchange;
- Section 7 explains how the walker trues to follow the 5 second rule;
- And finally Section 9 explains what to debug output to expect.

2 IP addresses and member identities

We designed Dispersy with a social overlay in mind, it uses public/private key pairs to prove the identities of participating peers. A key pair represents a single Member instance which we use to sign our messages and verify messages created by other peers.

However, we can not assume that a member will keep using the same IP address (i.e. IP addresses may change between sessions) or even that someones IP address is the same for everyone else in the overlay (i.e. someone behind a symmetric NAT will use different ports for communication with other peers).

Because of this we use Candidate instances to represent IP addresses. A Candidate instance maintains a list of Member instances that might be available at its IP/port combination, furthermore, the Candidate maintains time stamps to determine a category which determines how we can use it while building the neighbourhood.

2.1 Candidate categories

A Candidate is always in one of the following four categories:

walk: when we received an introduction-response in response to sending an introduction-request to this Candidate no more than *walk lifetime* seconds ago;

stumble: when the category is *not walk* and we received an introduction-request from this Candidate no more than *stumble lifetime* seconds ago;

intro: when the category is *neither walk nor stumble* and the introduction to this Candidate was no more than *intro lifetime* seconds ago;

none: in all other cases.

Walk lifetime and stumble lifetime are both set to 57.5 seconds. We have chosen this value with regard to most NAT boxes closing a punctured 'hole' 60 seconds after receiving the last packet.

We have chosen 27.5 seconds for the intro lifetime with regard to most NAT boxes closing a punctured 'hole' 30 seconds after puncturing the hole without receiving any packets though it.

2.2 (Un)verified candidates

There are two main methods to obtain available Candidate instances:

`dispersy_yield_candidates` returns an iterator with all walk, stumble, and intro-Candidate instances, in a randomised order. Note that intro-Candidates are *unverified*, i.e. we have only heard about their existence not actually had any contact with them ourselves.

`dispersy_yield_verified_candidates` returns an iterator with all walk and stumble-Candidate instances, in a randomised order. In most cases verified candidates are better than unverified ones.

2.3 Being eligible for walk

It is not always allowed to send an introduction request to a Candidate. We call this being *eligible* for a walk. A Candidate is eligible for a walk when it meets the following two criteria:

1. the category is either walk, stumble, or intro, and
2. the previous walk to this candidate was more than *eligible delay* seconds ago.

We have chosen 27.5 seconds for the eligible delay, with the exception of bootstrap candidates which require a 57.5 seconds delay. This delay ensures that (bootstrap) peers are not contacted to frequently. This feature was initially introduced to prevent 'tracker hammering'.

2.4 References to the source code

The file dispersy/candidate.py defines the delay and lifetime values discussed in this section, aswell as the Candidate class which provides methods to determine and influence the category, see below:

```
CANDIDATE_ELIGIBLE_DELAY = 27.5
CANDIDATE_ELIGIBLE_BOOTSTRAP_DELAY = 57.5
CANDIDATE_WALK_LIFETIME = 57.5
CANDIDATE_STUMBLE_LIFETIME = 57.5
```

```
CANDIDATE_INTRO_LIFETIME = 27.5
CANDIDATE_LIFETIME = 180.0

class WalkCandidate(Candidate):
    def get_category(self, now): pass
    def walk(self, now, timeout_adjustment): pass
    def walk_response(self): pass
    def stumble(self, now): pass
    def intro(self, now): pass
    def is_eligible_for_walk(self, now): pass
```

The file dispersy/community.py defines the Community class which contains the methods used to obtain Candidate instances in the neighborhood:

```
class Community(object):
    def dispersy_yield_candidates(self): pass
    def dispersy_yield_verified_candidates(self): pass
```

3 Who to walk towards

In **phase 1** of the walk schema (see Section 1) peer A chooses a known peer B from its neighbourhood and sends it an introduction-request. Method `dispersy_get_walk_candidate()` chooses peer B and returns a Candidate instance pointing to it, or it returns None when no eligible candidates are available.

Choosing a Candidate to walk towards heavily influences how large your neighbourhood will be. Based on your walks alone you will know approximately 11 Candidates, since 11 walks take place within the 57.5 seconds *walk lifetime* window. However, incoming walks from unknown peers also increase your neighbourhood, based on the number of peers choosing to walk towards you within the 57.5 seconds *stumble lifetime* window.

We designed the default `dispersy_get_walk_candidate()` to return a semi-random (un)verified candidate while taking into account that malicious peers can easily pollute our neighbourhood by walking towards us from multiple distinct addresses, effectively adding an arbitrary number of stumble-Candidates to our neighbourhood.

When we assume that there is at least one eligible Candidate in every category we can give the following simplified representation of the selection strategy:

1. remove all *non-eligible* (bootstrap) Candidates;

2. group all remaining Candidates by their category;
3. select a Candidate based on the following distribution:
    - 49.75% chance to revisit the *oldest* walk-Candidate;
    - 24.825% chance for the *oldest* stumble-Candidate;
    - 24.825% chance for the *oldest* intro-Candidate;
    - 0.5% chance for a *random* bootstrap-Candidate.

Table 1 contains all possible combinations, the first column *has-WSIB* specifies if there is at least one walk, stumble, intro, or bootstrap candidate available. For example, 1000 means that the only available candidates are walk candidates, hence there is a 100% chance to for `dispersy_get_walk_candidate()` to return a walk-candidate.

Table 1: Chance to select a category based depending on which categories has eligible candidates.

has-WSIB	walk	stumble	intro	boot	none
0000					100%
0001				100%	
0010			100%		
0011			99.5%	0.5%	
0100		100%			
0101		99.5%		0.5%	
0110		50%	50%		
0111		49.75%	49.75%	0.5%	
1000	100%				
1001	99.5%			0.5%	
1010	50%		50%		
1011	49.75%		49.75%	0.5%	
1100	50%	50%			
1101	49.75%	49.75%		0.5%	
1111	49.75%	24.825%	24.825%	0.5%	

3.1 Dissemination experiments

During experiments where dissemination speed is important, we suggest to only visit bootstrap-Candidates during the bootstrap process. Otherwise there is a 0.5% chance each step to visit a bootstrap peer and not get any new data (since the bootstrap peers do not participate in data dissemination). This would result in the combinations shown in Table 2. The diff in `./`

`minimal_bootstrap.diff` accomplishes this.

Table 2: Suggested chance to select a category based depending on which categories has eligible candidates.

has-WSIB	walk	stumble	intro	boot	none
0000					100%
0001				100%	
0010			100%		
0011			100%		
0100		100%			
0101		100%			
0110		50%	50%		
0111		50%	50%		
1000	100%				
1001	100%				
1010	50%		50%		
1011	50%		50%		
1100	50%	50%			
1101	50%	50%			
1111	50%	25%	25%		

3.2 References to the source code

The file dispersy/community.py defines the method discussed in this section, see below:

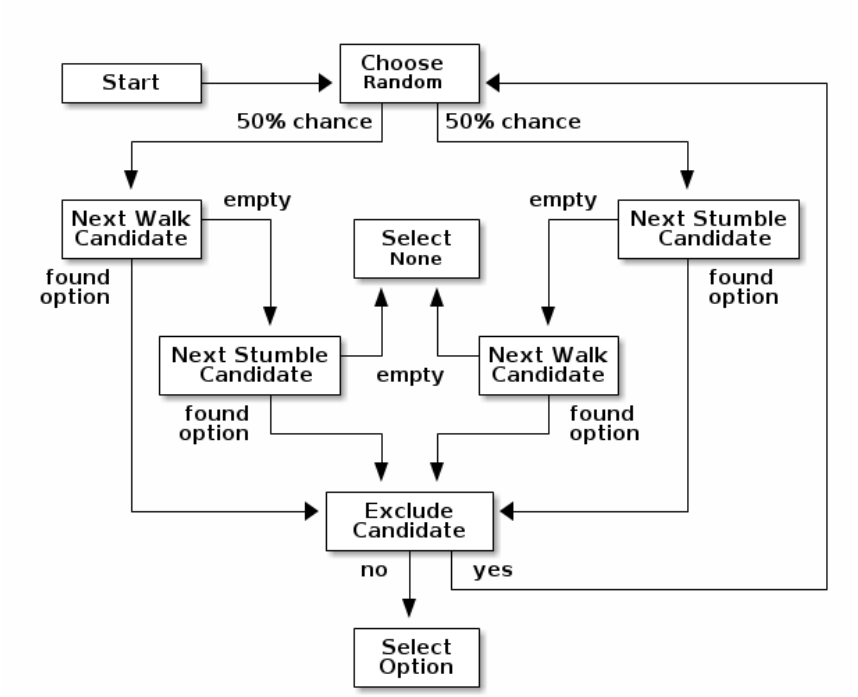
```
class Community(object):
    def dispersy_get_walk_candidate(self): pass
```

4 Who to introduce

In **phase 2** of the walk schema (see Section 1) peer B chooses a known peer C from its neighbourhood and introduces it to peer A. Method `dispersy_get_introduce_candidate(exclude_candidate)` chooses peer C from the verified (and not excluded) available candidates and returns it, or, when no candidates are available, it returns None.

We designed `dispersy_get_introduce_candidate(exclude_candidate)` to return a verified candidate in semi *round robin* fashion. To this end

each Community maintains two dynamic iterators `_walked_candidates` and `_stumbled_candidates` which iterate over all walk-Candidates and stumble-Candidates in round-robin, respectively.



The above schema shows how we select a Candidate, however, in most cases we can simplify it as follows:

1. choose either the walk-Candidate or stumble-Candidate iterator;
2. select the next Candidate in the iterator if it is not excluded, otherwise go back to step 1.

4.1 Candidate exclusion

There are reasons why we can not introduce one candidate to another. We can not introduce peer C to A when:

- when C and A are the same Candidate;
- when C is behind a tunnel while A is not behind a tunnel;
  At the end of 2012 we introduced the ability for Dispersy to recognise the `FFFFFFFF` tunnel prefix, older Dispersy clients will believe the prefix is part of the message, making them unable to decode it. Because we can not distinguish between older and newer code we are currently

assuming all code is 'old'.

- when C and A are both behind a NAT that changes the outgoing port number and they are not within the same LAN.

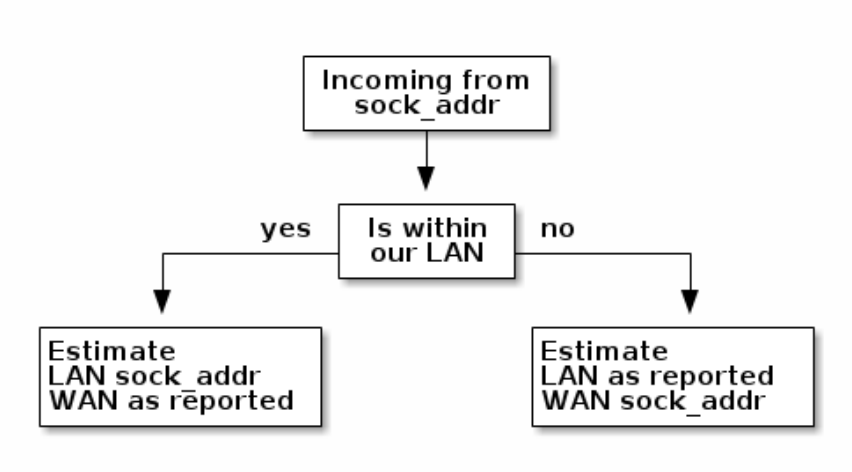
4.2 References to the source code

The file dispersy/community.py defines the method discussed in this section, see below:

```
class Community(object):
    def dispersy_get_introduce_candidate(self, exclude_candidate): pass
```

5 LAN and WAN address estimation

In **phase 2** of the walk schema (see Section 1) peer B tries to estimate the LAN and WAN address of peer A, it does this using the address reported in the UDP header (i.e. the `sock_addr`) of the incoming introduction-request combined with the WAN and LAN address that A reports that it has. We follow the schema shown below:



The estimation takes place in the `estimate_lan_and_wan_addresses(sock_addr, lan_addr, wan_addr)` method and uses a simple assumption: when peer B sees that the message originated from within the same LAN it will assume that peer A's LAN address is the `sock_addr`. But when the message originated from outside its LAN then peer A's WAN address is the `sock_addr`.

Dispersy determines weather an address is within its own LAN by checking if it corresponds with one of its local interfaces, with regards to its

netmask. We do this using the method `_get_interface_addresses()` and the `Interface` instances that it returns.

Peer B uses the result of this estimation to update the `lan_address` and `wan_address` properties of the Candidate instance pointing to peer A. These values are also added to the introduction response, allowing peer A to assess its own WAN address, as discusses in Section 6.

5.1 References to the source code

The file dispersy/dispersy.py defines the methods discussed in this section, see below:

```
class Dispersy(object):
    @staticmethod
    def _get_interface_addresses():
    def estimate_lan_and_wan_addresses(self, sock_addr, lan_address, wan_address): pas
```

6 WAN address voting

In **phase 2** of the walk schema (see Section 1) peer A receives an introduction-response containing the LAN and WAN address that peer B believes it has. This *dial back* allows peer A to determine how other peers perceive it, and thereby weather a NAT is affecting its address.

Most of the magic happens in the method `wan_address_vote(address, B)` and goes roughly as follows:

1. remove whatever B voted for before;
2. if the address is valid and B is outside our LAN then add the vote;
3. select the new address as our WAN address if it has equal or more votes than our current WAN address;
   Note: when we change our WAN address we also re-evaluate our LAN address.
4. determine our connection type based on the following rules:
   public when all votes have been for the same address and our LAN and WAN addresses are the same;
   symmetric-NAT when we have votes for more than one different addresses;
   unknown in all other cases.

6.1 Cleanup old voting data

Eventually we must remove old votes. Dispersy does this by periodically *(every five minutes)* checking for obsolete Candidate instances. Where we consider a Candidate to be obsolete when the last walk, stumble, or intro was more than *lifetime* seconds ago, where lifetime is three minutes.

This means that it can take anywhere between five and eight minutes before removing old votes.

6.2 References to the source code

The file dispersy/dispersy.py defines the methods discussed in this section, see below:

```
class Dispersy(object):
    def wan_address_unvote(self, voter): pass
    def wan_address_vote(self, address, voter): pass
```

7 The 5 second rule

When we decided on the design of the walker we took into account the following factors:

1. a significant number of NAT devices close a port after 60 seconds;
2. taking a step involves performing the bloom filter synchronisation;

Obviously when we take more steps the neighbourhood will contain more walk and intro-Candidates (and since other peers also take more steps the neighbourhood will also, on average, contain more stumble-Candidates). This would advocate taking as many steps as possible.

However, every step also has a cost associated to it, the majority being in the bloom filter synchronisation. At the time Dispersy we wanted every step to perform a synchronisation, and given that some peers might receive multiple incoming walks around the same time, we decided on a reserved value of 5 seconds. We expect this to be sufficient to perform one synchronisation for ourselves and, in the worst case, multiple incoming synchronisations.

Nowadays we have introduced mechanisms to reduce the workload by not always performing a bloom filter synchronisation, hence the 5 second rule is not strictly necessary anymore, however, the code contains constants derived from 5 seconds, making it difficult to change (see 7.3).

7.1 Walking in a single overlay

Doing a step usually includes creating a bloom filter, therefore this can be one of the most CPU intensive parts of Dispersy. Below we show a naive approach, where we simply schedule each walk 5 seconds after the last completed. For the purpose of simplicity we will assume that it takes 1 second to create a bloom filter. This example holds choosing a more realistic value.

The schematic below shows that creating the bloom filter is causing walk X to take a step once every 6 seconds instead of every 5 seconds. Furthermore, a large delay caused by task T is increasing the gap between walks even further, resulting in only 7 walks instead of the expected 10.

```
       ever widening gaps between steps
+----+----+----+----+----+----+----+----+----+  (time line)
            TT            TT            TT      (task T)
X     X       X     X       X     X       X     (walk overlay X)
```

7.2 Walking in multiple overlays

While ever widening gaps between steps is already a bad thing, it will only get worse when we need to maintain multiple overlays at the same time. In this case the naive approach would result in both overlays X and Y walking immediately after one another, causing a spike in CPU traffic, as seen in the schematic below.

```
   ever widening gaps with multiple overlays
+----+----+----+----+----+----+----+----+----+  (time line)
            TT            TT            TT      (task T)
X     X       X     X       X     X       X     (walk overlay X)
   Y     Y     Y     Y       Y     Y       Y    (walk overlay Y)
```

We address both of these problems by what we call a *self healing walker*, implemented in the `_candidate_walker` method. This walker takes into account both the number of overlays and the time between walks in individual overlays. It results in the following schematic.

```
              self healing walker
+----+----+----+----+----+----+----+----+----+  (time line)
          TT            TT            TT      (task T)
X    X      X  x    X      X  x    X      X  x  (walk overlay X)
   Y     Y    Y   y    Y     Y   y    Y     Y   (walk overlay Y)
```

The self healing walker has two major features:

- predicting the time when the next walk should occur to remove the ever widening gaps of the naive approach;
- allowing more than one step in a single overlay within 5 seconds, as seen in the above schematic where the lower letter x and y are within 5 seconds of the previous step taken in its overlay.

To preserve resources Dispersy will tell a community not to perform a bloom filter synchronisation when the previous step was less than 4.5 seconds ago. This is a large performance boost since synchronisation is the most expensive part of taking a step.

When we detect that the previous walk in an overlay was more than 5 seconds ago, a *walk reset* will occur to ensure we do not walk to often. This is especially usefull when a computer running Dispersy goes into sleep mode, when it wakes up the walk may be hours behind, the walk reset will ensure that Dispersy doesn't try to catch up with the sleeping time by performing thousands of steps.

7.3 Walk multiplier

Sometimes it can be useful to change the 5 seconds delay between steps into something else. The problem is that all derived values must be appropriately changed. The best way to do this is to multiply all these values with the same constant.

The diff in walk_multiplier.diff modifies all constants (as known at October 2013). Changing the `WALK_MULTIPLIER` constant to 2 will result in a step every 10.0 seconds, i.e. slowing down the walker. Conversely, changing the constant to 0.5 will result in a step every 2.5 seconds, i.e. speeding up the walker.

7.4 References to the source code

The file dispersy/dispersy.py defines the method discussed in this section, see below:

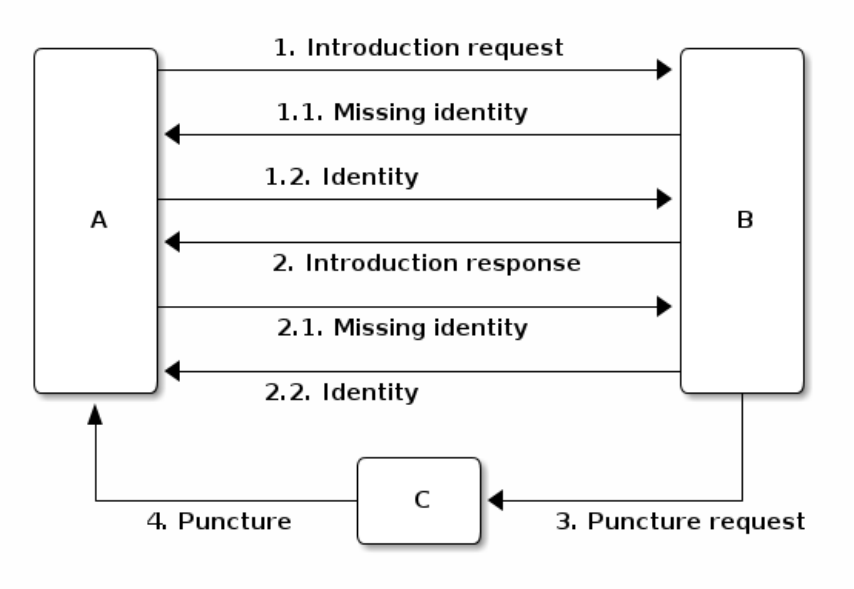
```
class Dispersy(object):
    def _candidate_walker(self): pass
```

8 Transferring the public key

The signed walker messages introduction-request and introduction-response used in Section 1 do not contain the public key of the signer, we transfer this

key using a missing-identity request and a identity message response.

Luckily this is only needed for public keys that we do not yet have, hence the first time that we encounter a peer the walk actually follows the figure below.



9 Debug output

Dispersy uses the standard Python logger to output different message levels, i.e. DEBUG, INFO, WARNING, and ERROR. When enabling DEBUG messages the logger in dispersy/endpoint.py will log all incoming and outgoing packets, including their name when possible. This can give valuable information when something is not behaving as expected.

9.1 Bootstrapping

To bootstrap an overlay we contact one of the bootstrap servers. When we have never encountered this bootstrap server before we need to exchange public keys. This results in the following DEBUG output:

```
 dispersy-introduction-request -> 130.161.211.245:6422   132 bytes
     dispersy-missing-identity <- 130.161.211.245:6422    51 bytes
             dispersy-identity -> 130.161.211.245:6422   177 bytes
dispersy-introduction-response <- 130.161.211.245:6422   126 bytes
```

```
    dispersy-missing-identity -> 130.161.211.245:6422    51 bytes
            dispersy-identity <- 130.161.211.245:6422   141 bytes
```

9.2 Building a neighbourhood

After taking some steps we will have started building our neighbourhood. Below we see that we contact someone at 74.96.92.***:7759, we no longer need to exchange public keys, but the incoming puncture message from 84.209.251.***:7759 is from someone not yet encountered, hence we exchange identities immediately.

```
 dispersy-introduction-request ->    74.96.92.***:7759   132 bytes
dispersy-introduction-response <-    74.96.92.***:7759   144 bytes
             dispersy-puncture <-  84.209.251.***:7759   125 bytes
     dispersy-missing-identity ->  84.209.251.***:7759    51 bytes
             dispersy-identity <-  84.209.251.***:7759   177 bytes
```

9.3 Candidate statistics

Dispersy provides the a logger with the name `dispersy-stats-detailed-candidates`. When enabling INFO level messages this logger will output a summary of its neighbourhood every five seconds. The example below is the summary as seen shortly after contacting 74.96.92.***:7759, see below:

```
--- 8164f55c2f828738fa779570e4605a81fec95c9d Community ---
  4.7s  E  intro   unknown       {192.168.1.35:7759 84.209.251.***:7759}
  9.7s  E  intro   unknown       {192.168.25.100:7759 177.157.54.***:7759}
 14.8s  E  intro   unknown       {192.168.0.3:34728 188.242.194.***:34728}
 19.9s  E  intro   unknown       {192.168.3.101:7759 67.33.160.***:7759}
 24.4s  E  intro   unknown       {192.168.178.21:7759 188.154.8.***:7759}
  5.0s     walk    unknown       {192.168.1.18:7759 74.96.92.***:7759}
 10.0s     walk    unknown       {192.168.0.100:7761 84.251.49.***:7761}
 15.0s     walk    symmetric-NAT {178.164.145.6:7759 94.21.97.***:7759}
 20.0s     walk    unknown       {192.168.1.27:7759 87.18.61.***:16409}
 25.0s     walk    symmetric-NAT {90.165.123.***:7759}
 30.0s  E  walk    unknown       {192.168.1.172:7759 76.115.137.***:7759}
 35.0s  E  walk    unknown       {192.168.2.3:7759 97.91.131.***:7759}
 45.0s  E  walk    unknown       {192.168.1.51:7749 109.208.189.***:7749}
 50.0s  E  walk    unknown       {192.168.0.3:7759 180.145.124.***:7759}
 55.0s  E  walk    unknown       {192.168.0.2:7759 83.153.18.***:7759}
```

The summary shows that the Candidate at 74.96.92.***:7759 is currently a walk-Candidate with age 5.0 seconds, i.e. we sent the introduction-request 5.0 seconds ago.

Furthermore, there is an intro-Candidate at 84.209.251.***:7759, which is the introduced Candidate from when we received a response to this walk 4.7 seconds ago. Note that this Candidate has the character *E* which signifies that this Candidate is eligible for a walk.