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|--|-----------------------------------|--|
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| Internet-Draft | Microsoft Corporation | |
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| Intended status: Standards Track | CERNET Center/Tsinghua University | |
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| | December 14, 2009 | |

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IPv6 Addressing of IPv4/IPv6 Translators draft-ietf-behave-address-format-02.txt

Abstract

This document discusses the algorithmic translated to a corresponding IPv4 address, and vice versa, using only statically configured information. It defines a Well-Known Prefix for use in algorithmic translations, while allowing organizations to also use Network Specific Prefixes when appropriate. Algorithmic translation is used in IPv4/IPv6 translators, as well as other types of proxies and gateways (e.g., for DNS) used in IPv4/IPv6 scenarios.

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1. Introduction

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This document is part of a series of IPv4/IPv6 translation documents. A framework for IPv4/IPv6 translation is discussed in

[\[I-D.ietf-behave-v6v4-framework\]](#) (Baker, F., Li, X., Bao, C., and K. Yin, "Framework for IPv4/IPv6 Translation," October 2009.), including a taxonomy of scenarios that will be used in this document. Other documents specify the behavior of various types of translators and gateways, including mechanisms for translating between IP headers and other types of messages that include IP addresses. This document specifies how an individual IPv6 address is translated to a corresponding IPv4 address, and vice versa, in cases where an algorithmic mapping is used. While specific types of devices are used herein as examples, it is the responsibility of the specification of such devices to reference this document for algorithmic mapping of the addresses themselves.

This document reserves a "Well-Known Prefix" for use in an algorithmic mapping. The value of this IPv6 prefix is:

64:FF9B::/96

[Section 2 \(IPv4 Embedded IPv6 Address Format\)](#) describes the format of "IPv4 Embedded IPv6 addresses", i.e. - IPv6 addresses in which 32 bits contain an IPv4 address.

[Section 3 \(Deployment Guidelines and Choices\)](#) discusses the choice of prefixes, the use of the Well-Known Prefix, and the use of embedded addresses with stateless and stateful translation.

[Section 4 \(Security Considerations\)](#) discusses security concerns.

1.1. Applicability Scope

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This document is part of a series defining address translation services. We understand that the address format could also be used by other interconnection methods between IPv6 and IPv4, e.g. methods based on encapsulation. If encapsulation methods are developed by the IETF, we expect that their descriptions will document their specific use of IPv4 Embedded IPv6 Addresses.

1.2. Notations

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This document makes use of the following terms:

IPv4/IPv6 translator: an entity that translates IPv4 packets to IPv6 packets, and vice versa. It may do "stateless" translation, meaning that there is no per-flow state required, or "stateful" translation where per-flow state is created when the first packet in a flow is received.

Address translator:

any entity that has to derive an IPv4 address from an IPv6 address or vice versa. This applies not only to devices that do IPv4/IPv6 packet translation, but also to other entities that manipulate addresses, such as name resolution proxies (e.g. DNS64 [\[I-D.ietf-behave-dns64\]](#) (Bagnulo, M., Sullivan, A., Matthews, P., and I. Beijnum, "DNS64: DNS extensions for Network Address Translation from IPv6 Clients to IPv4 Servers," October 2009.)) and possibly other types of Application Layer Gateways (ALGs).

Well-Known Prefix: the IPv6 prefix defined in this document for use in an algorithmic mapping.

Network Specific Prefix: an IPv6 prefix assigned by an organization for use in algorithmic mapping. Options for the Network Specific Prefix are discussed in [Section 3.3 \(Choice of Prefix for Stateless Translation Deployments\)](#) and [Section 3.4 \(Choice of Prefix for Stateful Translation Deployments\)](#).

IPv4 Embedded IPv6 addresses: IPv6 addresses in which 32 bits contain an IPv4 address. These addresses can be used to represent IPv4 hosts to hosts in an IPv6 network. Their format is described in [Section 2 \(IPv4 Embedded IPv6 Address Format\)](#).

IPv4-translatable IPv6 addresses: IPv6 addresses assigned to IPv6 hosts for use with stateless translation. They are a variant of embedded addresses, and follow the format described in [Section 2 \(IPv4 Embedded IPv6 Address Format\)](#).

2. IPv4 Embedded IPv6 Address Format

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IPv4 Embedded IPv6 Addresses are composed of a variable length prefix, the embedded IPv4 address, and a variable length suffix, as presented in the following diagram, in which PL designates the prefix length:

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|PL| 0-----32--40--48--56--64--72--80--88--96--104-112-120-|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|32|    prefix    |v4(32)          | u | suffix          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|40|    prefix          |v4(24)      | u |(8)| suffix          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|48|    prefix          |v4(16) | u | (16) | suffix          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|56|    prefix          |(8)| u | v4(24) | suffix          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|64|    prefix          | u | v4(32) | suffix          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|96|    prefix          | v4(32) |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

In these addresses, the prefix shall be either the "Well-Known Prefix", or a "Network Specific Prefix" unique to the organization deploying the address translators.

Various deployments justify different prefix lengths. The tradeoff between different prefix lengths are discussed in [Section 3.3 \(Choice of Prefix for Stateless Translation Deployments\)](#) and [Section 3.4 \(Choice of Prefix for Stateful Translation Deployments\)](#).

Bits 64 to 71 of the address are reserved for compatibility with the host identifier format defined in the IPv6 addressing architecture [\[RFC4291\] \(Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture," February 2006.\)](#). These bits MUST be set to zero. When using a /96 prefix, the administrators MUST ensure that the bits 64 to 71 are set to zero. A simple way to achieve that is to construct the /96 Network Specific Prefix by picking a /64 prefix, and then adding four octets set to zero.

The IPv4 address is encoded following the prefix, most significant bits first. Depending of the prefix length, the 4 octets of the address may be separated by the reserved octet "u", whose 8 bits MUST be set to zero. In particular:

- *When the prefix is 32 bits long, the IPv4 address is encoded in positions 32 to 63.

- *When the prefix is 40 bits long, 24 bits of the IPv4 address are encoded in positions 40 to 63, with the remaining 8 bits in position 72 to 79.

- *When the prefix is 48 bits long, 16 bits of the IPv4 address are encoded in positions 48 to 63, with the remaining 16 bits in position 72 to 87.

*When the prefix is 56 bits long, 8 bits of the IPv4 address are encoded in positions 56 to 63, with the remaining 24 bits in position 72 to 95.

*When the prefix is 64 bits long, the IPv4 address is encoded in positions 72 to 103.

*When the prefix is 96 bits long, the IPv4 address is encoded in positions 96 to 127.

There are no remaining bits, and thus no suffix, if the prefix is 96 bits long. In the other cases, the remaining bits of the address constitute the suffix. These bits are reserved for future extensions, and SHOULD be set to a zero.

2.1. Text Representation

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IPv4 embedded IPv6 addresses will be represented in text in conformity with section 2.2 of [\[RFC4291\] \(Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture," February 2006.\)](#). IPv4 embedded IPv6 addresses constructed using the Well Known Prefix or a /96 Network Specific Prefix may be represented using the alternative form presented in section 2.2 of [\[RFC4291\] \(Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture," February 2006.\)](#), with the embedded IPv4 address represented in dotted decimal notation. Examples of such representations are presented in [Table 1 \(Text representation of IPv4 embedded IPv6 addresses\)](#).

| Prefix | IPv4 address | IPv4 embedded IPv6 address |
|-----------------------|--------------|------------------------------|
| 2001:DB8:100::/32 | 13.1.68.3 | 2001:DB8:D01:4403:: |
| 2001:DB8:100::/40 | 13.1.68.3 | 2001:DB8:10D:0144:3:: |
| 2001:DB8:102::/48 | 13.1.68.3 | 2001:DB8:102:D01:44:300:: |
| 2001:DB8:102::/48 | 13.1.68.3 | 2001:DB8:102:D01:44:300:: |
| 2001:DB8:102:300::/56 | 13.1.68.3 | 2001:DB8:102:30D:1:4403:: |
| 2001:DB8:102:304::/64 | 13.1.68.3 | 2001:DB8:102:304:D:144:300:: |
| 2001:DB8:102:304::/96 | 13.1.68.3 | 2001:DB8:102:304::13.1.68.3 |
| 64:FF9B::/96 | 13.1.68.3 | 64:FF9B::13.1.68.3 |

Table 1: Text representation of IPv4 embedded IPv6 addresses

The Network Specific Prefixes in [Table 1 \(Text representation of IPv4 embedded IPv6 addresses\)](#) are derived from the IPv6 Prefix reserved for documentation in [\[RFC3849\] \(Huston, G., Lord, A., and P. Smith, "IPv6 Address Prefix Reserved for Documentation," July 2004.\)](#).

3. Deployment Guidelines and Choices

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3.1. Deployment Using the Well-Known Prefix

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The Well-Known Prefix MAY be used by organizations deploying translation services.

The Well-Known Prefix SHOULD NOT be used to construct IPv4 translatable addresses. The host served by IPv4 translatable IPv6 addresses should be able to receive IPv6 traffic bound to their IPv4 translatable IPv6 address without incurring intermediate protocol translation. This is only possible if the specific prefix used to build the IPv4 translatable IPv6 addresses is advertized in inter-domain routing, and this kind of specific prefix advertisement is not supported with the Well-Known Prefix, as explained in [Section 3.2 \(Impact on Inter-Domain Routing\)](#).

The Well-Known Prefix MUST NOT be used to represent non global IPv4 addresses, such as those defined in [\[RFC1918\] \(Rekhter, Y., Moskowitz, R., Karrenberg, D., Groot, G., and E. Lear, "Address Allocation for Private Internets," February 1996.\)](#). Doing so would introduce ambiguous IPv6 addresses.

3.2. Impact on Inter-Domain Routing

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The Well-Known Prefix MAY appear in inter-domain routing tables, if service providers decide to provide IPv6-IPv4 interconnection services to peers. Advertisement of the Well-Known Prefix SHOULD be controlled either by upstream and/or downstream service providers owing to inter-domain routing policies, e.g., through configuration of BGP [\[RFC4271\] \(Rekhter, Y., Li, T., and S. Hares, "A Border Gateway Protocol 4 \(BGP-4\)," January 2006.\)](#). Organizations that advertize the Well-Known Prefix in inter-domain routing MUST be able to provide IPv4/IPv6 address translation service.

When the IPv4/IPv6 translation relies on the Well-Known Prefix, embedded IPv6 prefixes longer than the Well-Known Prefix MUST NOT be advertised in BGP (especially e-BGP) [\[RFC4271\] \(Rekhter, Y., Li, T.,](#)

[and S. Hares, "A Border Gateway Protocol 4 \(BGP-4\)," January 2006.\)](#)

because this leads to importing IPv4 routing table into IPv6 one and therefore induces scalability issues to the global IPv6 routing table. Adjacent BGP speakers MUST ignore advertisements of embedded IPv6 prefixes longer than the Well-Known Prefix. BGP speakers SHOULD be able to be configured with the default Well-Known Prefix.

When the IPv4/IPv6 translation service relies on Network Specific Prefixes and stateless translation is used, the IPv4-translatable IPv6 prefixes MUST be advertised with proper aggregation to the IPv6 Internet. Similarly, if translators are configured with multiple Network Specific Prefixes, these prefixes MUST be advertised to the IPv6 Internet with proper aggregation.

3.3. Choice of Prefix for Stateless Translation Deployments

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Organization may deploy translation services using stateless translation. In these deployments, internal IPv6 hosts are addressed using "IPv4 translatable" IPv6 addresses, which enable them to be accessed by IPv4 hosts. The addresses of these external hosts are then represented in "IPv4 Embedded" IPv6 addresses.

Organizations deploying stateless IPv4/IPv6 translation SHOULD assign a Network Specific Prefix to their IPv4/IPv6 translation service. "IPv4 translatable" and "IPv4 Embedded" addresses MUST be constructed as specified in [Section 2 \(IPv4 Embedded IPv6 Address Format\)](#). IPv4 translatable IPv6 addresses MUST use the selected Network Specific Prefix. Both types of addresses SHOULD use the same prefix. Using the same prefix ensures that internal IPv6 hosts will use the most efficient paths to reach the hosts served by "IPv4 translatable" addresses.

The intra-domain routing protocol must be able to deliver packets to the hosts served by IPv4 translatable IPv6 addresses. This may require routing on some or all of the embedded IPv4 address bits. Security considerations detailed in [Section 4 \(Security Considerations\)](#) require that routers check the validity of the IPv4 translatable IPv6 source addresses, using some form of reverse path check.

Forwarding, and reverse path checks, should be performed on the combination of the "prefix" and the IPv4 address. In theory, routers should be able to route on prefixes of any length. However, routing on prefixes larger than 64 bits may be slower. But routing efficiency is not the only consideration in the choice of a prefix length.

Organizations also need to consider the availability of prefixes, and the potential impact of all-zeroes identifiers.

If a /32 prefix is used, all the routing bits are contained in the top 64 bits of the IPv6 address, leading to excellent routing properties. These prefixes may however be hard to obtain, and allocation of a /32 to a small set of IPv4 translatable addresses may be seen as wasteful.

In addition, the /32 prefix and a zero suffix leads to an all-zeroes interface identifier, an issue that we discuss in [Section 3.5 \(Choice of Suffix\)](#).

Intermediate prefix lengths such as /40, /48 or /56 appear as compromises. Only some of the IPv4 bits are part of the /64 prefixes. Reverse path checks, in particular, may have a limited efficiency. Reverse checks limited to the most significant bits of the IPv4 address will reduce the possibility of spoofing external IPv4 address, but would allow IPv6 hosts to spoof internal IPv4 translatable addresses. We propose here a compromise, based on using no more than 1/256th of an organization's allocation of IPv6 addresses for the IPv4/IPv6 translation service. For example, if the organization is an ISP, with an allocated IPv6 prefix /32 or shorter, the ISP could dedicate a /40 prefix to the translation service. An end site with a /48 allocation could dedicate a /56 prefix to the translation service, or possibly a /96 prefix if all IPv4 Translatable IPv4 Addresses are located on the same link.

The recommended prefix length is also a function of the deployment scenario. The stateless translation can be used for Scenario 1, Scenario 2, Scenario and Scenario 6 defined in [\[I-D.ietf-behave-v6v4-framework\] \(Baker, F., Li, X., Bao, C., and K. Yin, "Framework for IPv4/IPv6 Translation," October 2009.\)](#). For different scenarios, the prefix length recommendations are:

- *For scenario 1 (an IPv6 network to the IPv4 Internet) and scenario 2 (the IPv4 Internet to an IPv6 network), we recommend using a /40 prefix for an ISP holding a /32 allocation, and a /56 prefix for a site holding a /48 allocation.

- *For scenario 5 (an IPv6 network to an IPv4 network) and scenario 6 (an IPv4 network to an IPv6 network), we recommend using a /64 or a /96 prefix.

3.4. Choice of Prefix for Stateful Translation Deployments

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Organizations may deploy translation services based on stateful translation technology. An organization may decide to use either a Network Specific Prefix or the Well-Known Prefix for its stateful IPv4/IPv6 translation service.

When these services are used, IPv6 hosts are addressed through standard IPv6 addresses, while IPv4 hosts are represented by IPv4 embedded addresses, as specified in [Section 2 \(IPv4 Embedded IPv6 Address Format\)](#).

The stateful nature of the translation creates a potential stability issue when the organization deploys multiple translators. If several translators use the same prefix, there is a risk that packets belonging

to the same connection may be routed to different translators as the internal routing state changes. This issue can be mitigated either by assigning different prefixes to different translators, or by ensuring that all translators using same prefix coordinate their state. Stateful translation can be used in scenarios defined in [\[I-D.ietf-behave-v6v4-framework\]](#) (Baker, F., Li, X., Bao, C., and K. Yin, "Framework for IPv4/IPv6 Translation," October 2009.). The Well Known Prefix SHOULD be used in most scenarios, with two exceptions:

- *In all scenarios, the translation MAY use a Network Specific Prefix, if deemed appropriate for management reasons.

- *The Well-Known Prefix MUST NOT be used for scenario 3 (the IPv6 Internet to an IPv4 network), as this would lead to using the Well-Known Prefix with non global IPv4 addresses. That means a Network Specific Prefix MUST be used in that scenario, for example a /96 prefix compatible with the Well Known prefix format.

3.5. Choice of Suffix

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The address format described in [Section 2 \(IPv4 Embedded IPv6 Address Format\)](#) recommends a zero suffix. Before making this recommendation, we considered different options: checksum neutrality; the encoding of a port range; and a value different than 0.

The "neutrality checksum" option would give a chosen value to 16 of the suffix bits to ensure that the "IPv4 embedded" IPv6 address has the same 16 bit 1's complement checksum as the embedded IPv4 address. There have been discussion of this checksum in the working group mailing list, and some push to standardize a checksum format. However, we observed that a neutral checksum alone does not eliminate checksums computation during stateful translation, as only one of the two addresses would be checksum neutral. In the case of stateless translation, translators may want to recompute the checksum anyhow, to verify the validity of the translated datagrams. In the case of stateful translation, the Well Known Prefix was chosen to provide checksum neutrality. We thus chose the simplest alternative, to not specify a neutrality checksum.

There have been proposals to complement stateless translation with a port-range feature. Instead of mapping an IPv4 address to exactly one IPv6 prefix, the options would allow several IPv6 hosts to share an IPv4 address, with each host managing a different range of ports. But these schemes are not yet specified in work group documents. If a port range extension is needed, it could be defined later, using bits currently reserved as null in the suffix.

When a /32 prefix is used, an all-zero suffix results in an all-zero interface identifier. We understand the conflict with Section 2.6.1 of RFC4291, which specifies that all zeroes are used for the subnet-router anycast address. However, in our specification, there would be only one IPv4 translatable node in the /64 subnet, and the anycast semantic would not create confusion. We thus decided to keep the null suffix for now. (This issue does not exist for prefixes larger than 32 bits, such as the /40, /56, /64 and /96 prefixes that we recommend in [Section 3.3 \(Choice of Prefix for Stateless Translation Deployments\)](#).)

3.6. Choice of the Well-Known Prefix

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Before making our recommendation of the Well-Known Prefix, we were faced with three choices:

- *reuse the IPv4-mapped prefix, ::FFFF:0:0/96, as specified in RFC 2765 Section 2.1;
- *request IANA to allocate a /32 prefix,
- *or request allocation of a new /96 prefix.

We weighted the pros and cons of these choices before settling on the recommended /96 Well-Known Prefix.

The main advantage of the existing IPv4-mapped prefix is that it is already defined. Reusing that prefix will require minimal standardization efforts. However, being already defined is not just an advantage, as there may be side effects of current implementations. When presented with the IPv4-mapped prefix, current versions of Windows and MacOS generate IPv4 packets, but will not send IPv6 packets. If we used the IPv4-mapped prefix, these hosts would not be able to support translation without modification. This will defeat the main purpose of the translation techniques. We thus eliminated the first choice, and decided to not reuse the IPv4-mapped prefix, ::FFFF:0:0/96.

A /32 prefix would have allowed the embedded IPv4 address to fit within the top 64 bits of the IPv6 address. This would have facilitated routing and load balancing when an organization deploys several translators. However, such destination-address based load balancing may not be desirable. It is not compatible with STUN in the deployments involving multiple stateful translators, each one having a different pool of IPv4 addresses. STUN compatibility would only be achieved if the translators managed the same pool of IPv4 addresses and were able to coordinate their translation state, in which case there is no big advantage to using a /32 prefix rather than a /96 prefix.

According to Section 2.2 of [\[RFC4291\] \(Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture," February 2006.\)](#), in the legal textual representations of IPv6 addresses, dotted decimal can only

appear at the end. The /96 prefix is compatible with that requirement. It enables the dotted decimal notation without requiring an update to [\[RFC4291\] \(Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture," February 2006.\)](#). This representation makes the address format easier to use, and log files easier to read.

The prefix that we recommend has the particularity of being "checksum neutral". The sum of the hexadecimal numbers "0064" and "FF9B" is "FFFF", i.e. a value equal to zero in complement to 1 arithmetic. An IPv4 embedded IPv6 address constructed with this prefix will have the same complement to 1 checksum as the embedded IPv4 address.

4. Security Considerations

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4.1. Protection Against Spoofing

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By and large, address translators can be modeled as special routers, are subject to the same risks, and can implement the same mitigations. There is however a particular risk that directly derives from the practice of embedding IPv4 addresses in IPv6: address spoofing. An attacker could use an IPv4 embedded address as the source address of malicious packets. After translation, the packets will appear as IPv4 packets from the specified source, and the attacker may be hard to track. If left without mitigation, the attack would allow malicious IPv6 nodes to spoof arbitrary IPv4 addresses. The mitigation is to implement reverse path checks, and to verify throughout the network that packets are coming from an authorized location.

4.2. Secure Configuration

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The prefixes and formats need to be configured consistently among multiple devices in the same network (e.g., hosts that need to prefer native over translated addresses, DNS gateways, and IPv4/IPv6 translators). As such, the means by which they are learned/configured MUST be secure. Specifying a default prefix and/or format in implementations provides one way to configure them securely. Any alternative means of configuration is responsible for specifying how to do so securely.

5. IANA Considerations

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The Well Known Prefix falls into the range `::/8` reserved by the IETF. The prefix definition does not require an IANA action.

6. Acknowledgements

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Many people in the Behave WG have contributed to the discussion that led to this document, including Andrew Sullivan, Andrew Yourtchenko, Brian Carpenter, Dan Wing, Ed Jankiewicz, Fred Baker, Hiroshi Miyata, Iljitsch van Beijnum, John Schnizlein, Keith Moore, Kevin Yin, Magnus Westerlund, Margaret Wasserman, Masahito Endo, Phil Roberts, Philip Matthews, Remi Denis-Courmont, Remi Despres and William Waites. Marcelo Bagnulo is partly funded by Trilogy, a research project supported by the European Commission under its Seventh Framework Program.

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