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A P. Thubert, Ed.

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Yet Another Double Address and Translation Technique

Abstract

This document provides a mechanism named YADA to extend the current IPv4 Internet by interconnecting IPv4 realms via a common footprint called the shaft. YADA extends [[INT-ARCHI](#)] with the support of an IP-in-IP format used to tunnel packets across the shaft. This document also provides a bump-in-the-stack method to enable YADA on a legacy stack, e.g., to enable virtual machines without changing them. This document also provides a stateless address and IP header translation between YADA and IPv6 [[IPv6](#)] called YATT and extends [[IPv6-ADDRESSING](#)] for the YATT format. YADA and YATT can take place as a bump in the stack at either end, or within the network and enables an IPv6-only stack to dialog with an IPv4-only stack across a network that can be IPv6, IPv4, or mixed. YATT requires that the IPv6 stack owns a prefix that derives from a YADA address and the IPv4 stack is capable of YADA, so it does not replace a generic 4 to 6 translation mechanism for any v6 to any v4.

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1. Introduction

This document defines baby steps from an IPv4-only stack/gateway/ISP to an IPv6-only version. The goal is to end with dual stack and Carrier-Grade Network Address Translators (CG-NATs). The first step called Yet Another Double Address (YADA) uses IPv4-only signaling. The second step called Yet Another Translation Technique (YATT) offers an IPv6-only signaling that is interchangeable with YADA, so any router or stack may turn one into the other, allowing the stack or the link to be one version only. A YADA-enabled IPv4 stack can thus talk to a YATT-enabled IPv6 stack with neither CG-NATs nor dual stack network in between, but a stack that is not aware of this specification will still need a traditional NAT approach to communicate.

The effort in this specification is to provide enough value / incentive for an IPv4-only stack/gateway/ISP to make the step towards YADA, as a push towards IPv6, and for an IPv6-only stack to support YATT on top to pull IPv4 space in IPv6, with a low barrier for making the baby step. For IPv4, going YADA expands the size/

reach of the Internet, and allows multiple parties to build their own IPv4 realm, with control of interconnection with other realms. For an IPv6 node, supporting YATT provides connectivity to the YADA world, and automatically assigns a prefix in the node.

This first mechanism called YADA allows to grow the Internet beyond the current IPv4 [[IPv4](#)] realm that limits its capacity to form public addresses. Depending on the assignments to be made, the model allows to reuse all IP addresses and all Autonomous System Number (ASN) currently available in the internet hundreds to millions of times. This is achieved by interconnecting IPv4 realms via a common footprint called the shaft.

In the analogy of a building, the ground floor would be the Internet, and each additional floor would be another IPv4 realm. The same surface of floor is available in each level, analog to the full IPv4 addressing that is available in each realm. The same footprint is dedicated across the building levels for the elevator shaft. The elevator shaft enables a third dimension that spans across the levels and allows to traverse from any level to any other level. The elevator shaft cannot be used for living or office space.

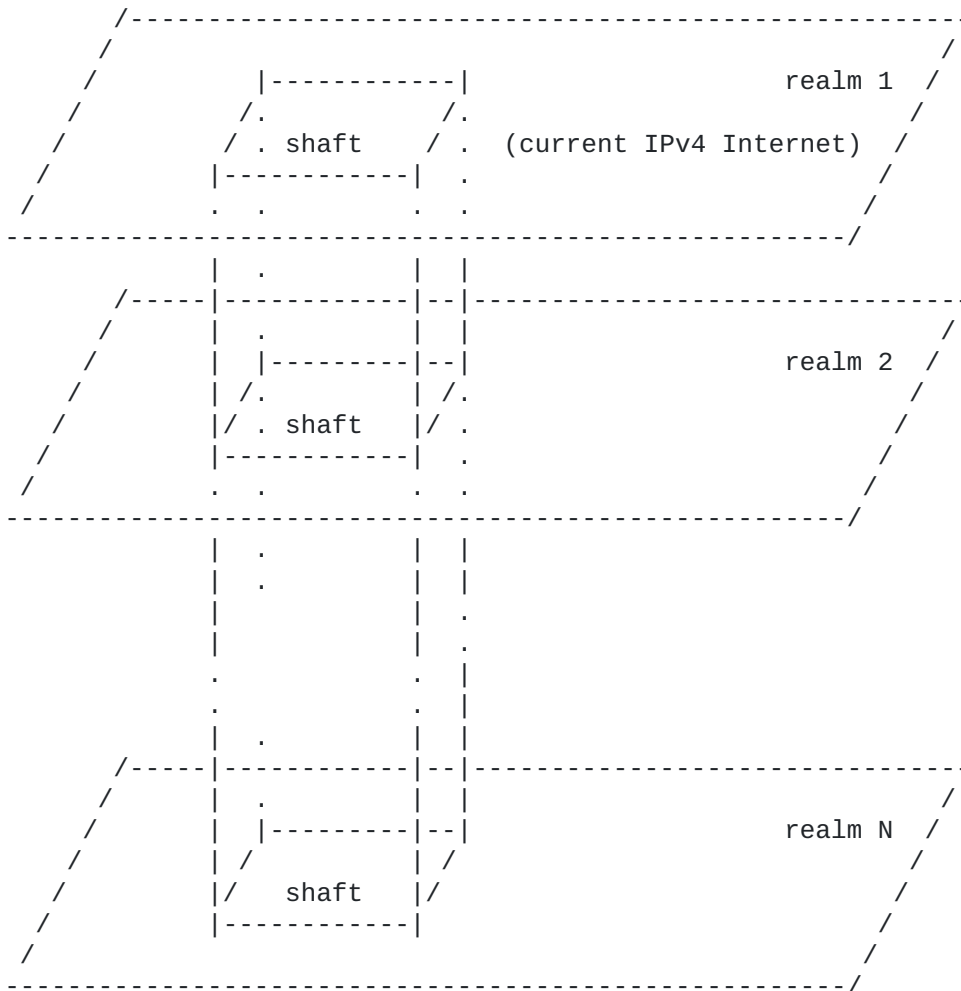


Figure 1: The shaft

By analogy, YADA assigns IPv4 prefixes to a multinternet shaft; those prefixes are common across the realms that are interconnected by the shaft. A single /24 IPv4 prefix assigned allows for > 250 times the capacity of the Internet as we know it at the time of this writing. Multiple prefixes can be assigned to the shaft for unicast and multicast communications, and each realm needs at least one unicast address in the shaft called its realm address. A YADA address is formed by the tuple (realm address, IPv4 address) and is advertised in DNS as a new double-A record.

YADA leverages IP-in-IP encapsulation to tunnel packets across the shaft while normal IPv4 operations happen within a realm. YADA requires a change in the stack in the YADA endpoints that communicate with other realms to support the IP-in-IP YADA encapsulation. YADA also provides a bump in the stack method for legacy applications. More in [Section 5](#).

A second mechanism called Yet Another Translation Technique (YATT) translates the YADA format into flat IPv6 [[IPv6](#)]. For unicast addresses, YATT forms an IPv6 prefix by collating an well-known assigned short prefix, the realm address (in the shaft), and the host IPv4 address (locally significant within the realm). The resulting IPv6 prefix is automatically owned by the host that owns the IPv4 address in the realm. YATT then forms an IPv6 address for that host by collating a well-known Interface ID, so there's a one-to-one relationship between the YADA and the IPv6 address derived from it. More in [Section 6](#).

A key concept for this specification is that YADA (the IPv4 formulation) and YATT (the IPv6 formulation) represent the same thing. YADA uses IPv4 formats as plain IP-in-IP with no new extension. YATT uses IPv6 format with the IPv4 addresses encoded on the prefix. The formats are interchangeable, and a router can convert one to another as the packet flows over a next-hop link that can only carry the other address family.

2. Terminology

2.1. Glossary

This document often uses the following acronyms:

YADA: Yet Another Double Address

YATT: Yet Another Translation Technique

NAT: Network address Translation

IID: Interface ID

CG-NAT: Carrier Grade NAT

2.2. New Terms

This document often uses the following new terms:

IPv4 realm: A full IPv4 network like the current Internet. YADA does not affect the traditional IPv4 operations within a realm.

The shaft: The shaft refers to a collection of IPv4 unicast and multicast prefixes that are assigned to Inter-realm communications and cannot be assigned to hosts or multicast groups within a realm.

Realm address: An IPv4 address that derives from a shaft prefix.

Uni-realm address: A realm address that is unicast or anycast. A realm may have more than one Uni-realm address.

Multi-realm address: A realm address that is multicast and denotes a collection of realms.

YADA realm prefix: A prefix assigned to the shaft and from which realm addresses can be derived.

YADA NAT prefix:

A prefix assigned to the YADA bump-in-the-stack NAT operation.

Double-A or YADA address: A YADA address is a tuple (realm address, IPv4 address) where the IPv4 address is only significant within the realm denoted by the realm address.

YATT Space: An IPv6 range that is assigned for YATT operation.

YATT prefix: An IPv6 prefix that is derived from a YADA address by appending the YATT space prefix, the (truncated) realm address and the IPv4 address.

YATT-IID: A 64-bit assigned constant that is used in YATT to statelessly form an IPv6 address from a YATT prefix.

Multinternet: A collection of IPv4 realms interconnected using a common shaft.

3. Extending RFC 1122

YADA extends [[INT-ARCHI](#)] to add the capability for an IPv4 host to recognize an special IP-in-IP format as an inter-realm IPv4 packet and process it accordingly. It also adds a new DNS double-A record format that denotes a YADA address.

4. Extending RFC 4291

YATT extends [[IPv6-ADDRESSING](#)] to add the capability for an IPv4 host to recognize an special IPv6 format as an YATT address embedding a YADA address and process it accordingly. It also automatically derives the ownership of the YATT prefix associated to a owned YADA address.

5. YADA

YADA assigns IPv4 prefixes to a multinternet shaft; those prefixes must be the same across all the realms that are interconnected by the shaft. Multiple prefixes can be assigned to the shaft for unicast and multicast communications, and each realm needs at least one unicast address in the shaft called its realm address. A YADA address is formed by the tuple (realm address, IPv4 address) and is advertised in DNS as a new double-A record. Because the YADA prefixes are assigned for YADA, a packet that has either source or destination IPV4 address derived from a shaft prefix is a YADA packet.

YADA leverages IP-in-IP encapsulation to tunnel packets across the shaft for inter-realm communications, while the IPv4 operations within a realm are unaffected. The YADA address is found by using both inner and outer header and combining that information. The pair of IP headers is seen by a YADA stack as a single larger header though a non-YADA forwarder only needs the outer header and plain IPv4 operations to forward.

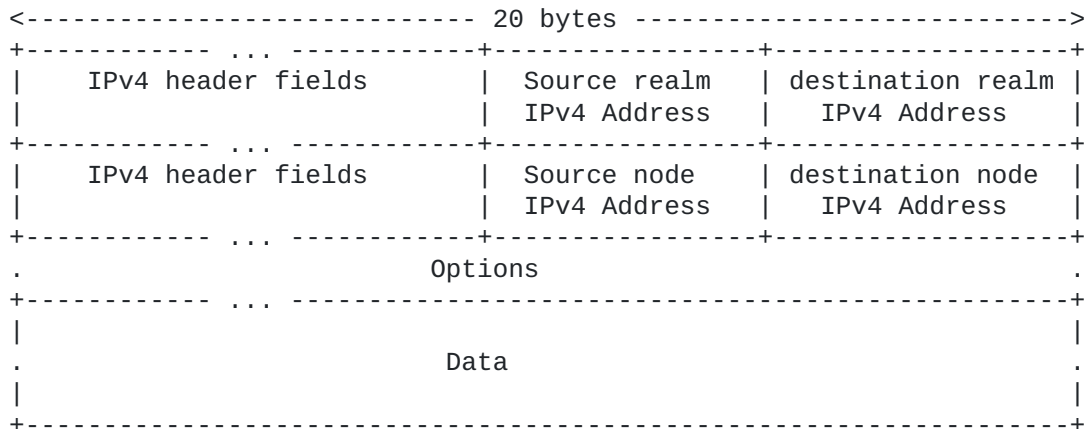


Figure 2: YADA format in the source realm

YADA requires a change in the stack in the YADA endpoints that communicate with other realms to support the YADA encapsulation. YADA also provides a bump in the stack method for legacy applications. YADA also requires a change for the routers that serve the shaft. Those routers play a special role for packets that are delivered from the shaft to the destination realm, and for ICMP errors across realms. All other IPv4 nodes in the realm continue to operate as before.

Routers serving the shaft advertise the shaft prefix(es) in their respective realms, and their realm addresses within the shaft, as host routes for unicast and anycast addresses. A stack that resolve a DNS name with a double-A record indicating a different realm generates an IP-in-IP packet, with the outer header indicating the source and destination realms, and the inner header indicating the source and destination IPv4 addresses within the respective realms, as shown in [Figure 3](#). The packet is forwarded down the shaft as is, using the normal longest match or multicast operation.

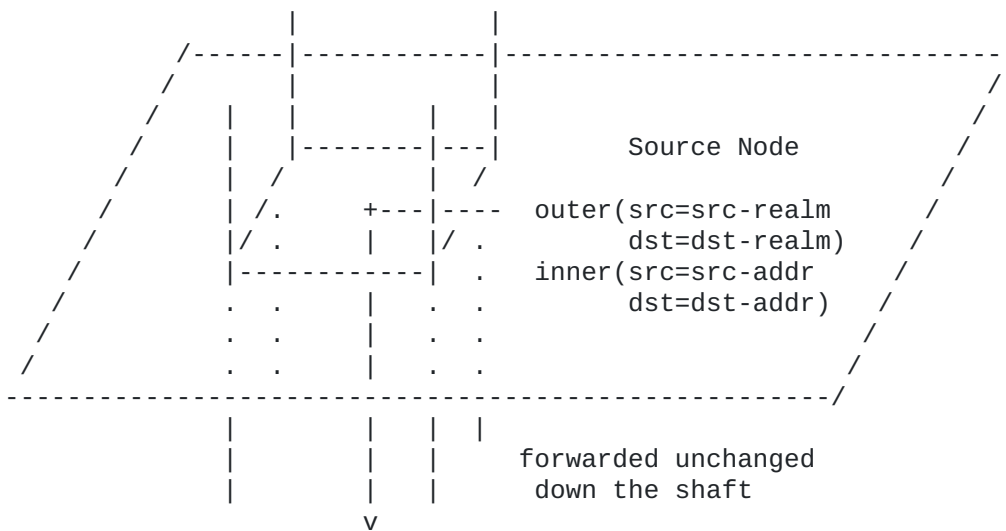


Figure 3: Packets Entering the shaft

The packet destination is an address in the shaft and it is attracted by a router that serves the shaft and advertises its prefixes in the source realm. Based on longest match, the router forwards the packet inside the shaft following the host route to a router that serves the destination realm. That router swaps the destination address in the inner and outer headers and forwards within its realm to the final destination, as shown in [Figure 4](#).

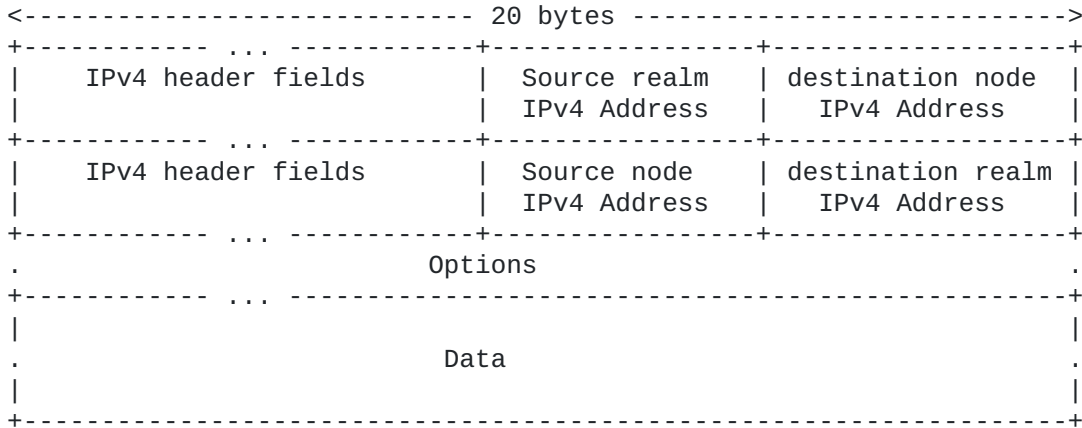


Figure 4: YADA format in the destination realm

In normal conditions, the stack of the destination node recognizes the YADA format and replies accordingly.

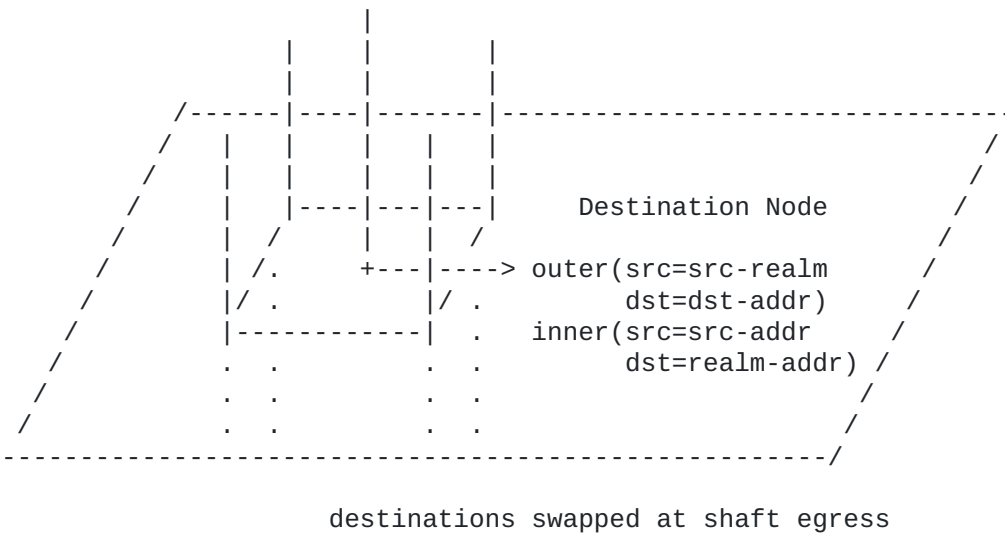


Figure 5: Packets Outgoing the shaft

In case of an error down the path or at the destination, if an ICMP message is generated by a node that is not YADA-aware, the message reaches the router that serves the shaft in the source realm. If the inner header is present in the ICMP payload, then the Router extracts it and forwards to the packet source. If the destination stack does not support YADA and decapsulates, the message reaches

the router that serves the destination realm which logs and drops. based on the log, the node may be updated, or the DNS records may be fixed to avoid pointing on a node that does not support YADA.

YADA requires the assignment of a second IPv4 prefix, this time for a internal NATing operation. A bump-in-the-stack intercepts the DNS lookups, and when the response yields a double-A record with a foreign realm, the record is augmented with an IPv4 address taken from a local NAT pool. When the stack sends a packet to that particular address, the bump-in-the-stack translates to the YADA format, using the information in the double-A record for the destination, and the local realm as source realm. The other way around, if a packet arrives with a YADA format but the stack does not support it, the bump-in-the-stack allocates an address from the pool, and NATs to IPv4 using that address as source.

YADA was initially published as USPTO 7,356,031, filed in February 2002.

6. YATT

A second mechanism called YATT translates the YADA format into flat IPv6.

```

+-----+-----+-----+-----+
|YATT |   Realm   |   IPv4   |   Well-Known   |
|Space|   Address  |   Address  |           IID   |
+-----+-----+-----+-----+
      <- YADA
           prefix ->
<----- YATT prefix ----->

```

Figure 6: YATT format

For unicast addresses, YATT forms an IPv6 prefix by collating an well-known assigned short prefix called the YATT space, the realm address, and the host IPv4 address (locally significant within the realm). The resulting IPv6 prefix is automatically owned by the host that owns the IPv4 address in the realm.

Depending on assignment, the leftmost piece realm prefix may be truncated if it is well-known, to allow the YATT space and the realm address to fit in a 32-bit DWORD. This way, the YATT prefix can be a full /64 prefix that is entirely owned by the host that owns the associated YADA address.

YATT then forms an IPv6 address for that host by collating a well-known Interface ID, so there's a one-to-one relationship.

The formats can not be strictly provided till the YATT space and YADA prefix are assigned. But say that the YATT Space is F000::/6 and the YADA prefix is 240.0.0.0/6. In that case the values perfectly overlap and the YATT format becomes as follows:

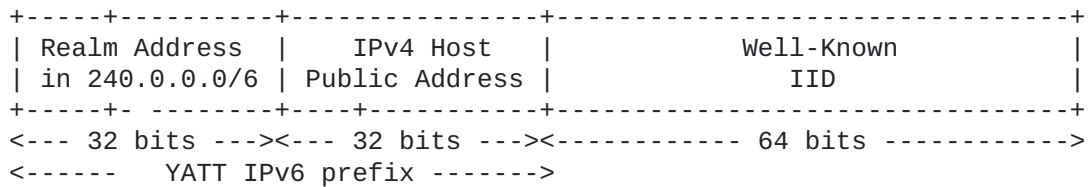


Figure 7: YATT format using 240.0.0.0/6

In that case, the NAT operation is a plain insertion. Depending on the assignment, it might be that the Realm address must be placed in full after YATT space. In that case, the length of the YATT prefix will be more than 64 bits.

Also, since 240.0.0.0/6 is currently unassigned, using it for the shaft would allow literally to reuse every ASN and every IPv4 address currently available in the Internet in each and every other realm and reallocate them in any fashion desirable in that realm.

If the network supports IPv6 to the shaft, it makes sense for the YADA host or the bump-in-the-stack to generate the packets in the YATT form natively. The shaft router must then attract the shaft YADA realm prefix in both IPv4 and YATT forms.

If the network is IPv4 only, the packets are still generated using IP-in-IP, and the YATT NAT operation may happen at the router that delivers the packet in the destination realm, if it is v6-only, or in the destination host, if its stack is v6-only.

YATT was initially published as USPTO 7,764,686, filed in December 2002.

7. The structure of the shaft

A 10 miles view of the shaft could be as follows: it is implemented in one IXP, spans all realms, and each realm has one address in the shaft, with one router serving that realm. The address of the realm is encoded in a loopback in the router, and advertised through an IGP inside the shaft, while BGP is used inside the realms but not inside the shaft. The shaft has a single large prefix that is advertised in each realm by the router that serves the shaft, and that is disaggregated into host routes inside the shaft.

None of the above is expected to remain true for long. As YADA and YATT get deployed, the shaft will be implemented in different sites over the world. A realm may be multihomed to be reached from a different physical instance of the shaft, meaning that the shaft is composed of either more prefixes or the shaft prefix is disaggregated. Multiple routers will serve the same realm with high availability and load balancing taking place inside the shaft to maintain connectivity. Some shafts may be deployed to interconnect only a subset of the realms, in which case those shafts would share a specific prefix that would not be advertised outside the concerned realms.

8. Applicability

YADA And YATT enable communication between YADA-enabled IPv4 nodes across realms, and with IPv6 nodes that own a YADA address from which a YATT address can be derived. Communication from a legacy IPv4 application/stack that is not YADA-enabled, or to an IPv6 address that is not a YATT address, is not provided.

Since the YATT translation is stateless, the header translation can happen anywhere in the network, e.g., as a bump in the stack at either end, or within the network, e.g., at the routers that serve the realms on the shaft. The shaft itself is expected to be dual stack to forward packets in their native form, either v4 or v6.

For a legacy IPv4 node to communicate with YADA-enabled IPv4 node in another realm, a NAT operation similar to NAT46 [[NAT-DEPLOY](#)], but between IPv4 and YADA addresses, is required. The same would be required to allow an IPv4-only YADA node to communicate with an IPv6 node a a non-YATT address.

In summary:

- *this specification does not allow any IPv4 legacy node to talk to any pure IPv6 node, and recognizes that this Graal may actually be a non-goal.

- *With YADA the current IPv4 Internet operations are not affected

- *YADA extends the IPv4-reachable world by creating (millions of) parallel realms and changing (only) the stack on the hosts that require inter-realm communication and specific routers at the ingress of the realms

- *A YADA node can talk (using IPv4) to a YATT node (using IPv6) with a stateless translation. The translation can happen anywhere in the network or in the stack.

- *a YATT node being an IPv6 can talk to any other IPv6 nodes.

9. Backwards Compatibility

YADA operation does not affect the intra-realm communication. The only affected stacks are the endpoints that communicate between realms leveraging YADA.

10. Security Considerations

11. IANA Considerations

This document requires the creation of a registry for IPv4 YADA realm prefixes, and the assignment of at least one YADA realm prefix.

This document requires the creation of a registry for IPv4 YADA NAT prefixes, and the assignment of at least one YADA NAT prefix.

This document requires the creation of a new record in the Resource Record (RR) TYPEs subregistry of the Domain Name System (DNS)

Parameters. The new record would be of type AA meaning a YADA address.

12. Acknowledgments

The author wishes to thank Greg Skinner as the first reviewer/contributor to this work.

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Author's Address

Pascal Thubert (editor)
Cisco Systems, Inc
Building D
45 Allee des Ormes - BP1200
06254 Mougins - Sophia Antipolis
France

Phone: [+33 497 23 26 34](tel:+33497232634)
Email: pthubert@cisco.com