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Coordinated Address Space Management architecture
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Abstract

IP addresses ~~work as~~are ~~a basic element~~key resources for providing broadband network services. However, the increase in number, diversity and complexity of modern network devices and services ~~creates~~ create unprecedented challenges for the currently prevailing approach of manual IP address management. Manually maintaining IP addresses could always be sub-optimal for IP resource utilization. Besides, it requires heavy human effort from network operators. To achieve high utilization and flexible scheduling of IP ~~network~~ addresses, it is necessary to automate the address scheduling process.

Mis en forme : Surlignage

This document describes an architecture for the IP address space management. It includes architectural concepts and components used in the CASM (Coordinated Address Space Management), with a focus on those interfaces to be standardized in the IETF.

Status of This Memo

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1. Introduction

~~The address space management is an integral part of any network management solution. However, the~~The increase in number, diversity and complexity of modern network devices and services ~~creates~~create unprecedented challenges for the currently prevailing approach of manual IP address management. Manually maintaining IP addresses could always be sub-optimal for IP resource utilization. Besides, it requires heavy human effort from network operators.

Another factor which drive this work is that ~~tThe~~ network architectures are rapidly changing with the migration toward private and public clouds. At the same time, application architectures are also evolving with a shift toward micro-services and multi-tiered approaches.

There is a pressing need to define a new address management system which can meet these diverse set of requirements. To achieve high utilization and flexible scheduling of IP ~~network~~ address resources, ~~Such~~ such a system should be capable of automating the address scheduling process. Also, ~~Such~~ such a system must be built with well-defined interfaces so users can easily migrate from one vendor to another without rewriting their network management systems.

This document defines a reference architecture ~~that should become the basis to develop a new~~ for such address management system. This system is called Coodinated Address Space Management (CSAM) system.

A series of use cases are defined in "Use Case Draft". For example, Broadband Network Gateway (BNG), which manages~~ a~~ routable IP addresses/prefixes on behalf of each subscriber, should be configured with the IP address pools allocated to subscribers. However, ~~currently~~ operators are facing with the address shortage problem, the remaining IPv4 address pools are usually quite scattered, no more than /24 per address pool in many cases. Therefore, it is complicated to manually configure the address pools on lots of Broadband Network Gateway (BNG) for operators. For large scale Metro Area Network (MAN), the number of BNGs can be up to over one hundred. Manual configuration on all the BNGs statically will not only greatly increase the workload, but also decrease the utilization efficiency of the address pools when the number of subscribers changes over time in the future. Let alone make sure appropriate prefix announcements are injected using the underlying routing for the sake of proper reachability. There is currently no automated and dynamic means which glue address/prefix allocation engines with forwarding engines of access nodes [I-D.petrescu-relay-route-pd-problem].

Commentaire [Med1]: Please add a reference.

~~Above is one example of use case, T~~There are other devices which may need to configure address pools as well. In this document, we propose a general mechanism to manage the address pools coordinately, which can be used in multiple use cases. With this approach, operators do not need to configure the address pools one by one manually or using home-made scripts and it also helps to use the address pools more efficiently.

2. Terminology

The following terms are used in this document:

CASM: Coordinated Address Space Management, a ~~newly-defined~~ general architecture which can automate IP address management for wide-variety of use cases.

IPAM: IP Address Management, a means of planning, tracking, and managing the Internet Protocol address space used in a network.

DA: An~~ device~~ agent within ~~the~~ a device, which contacts with CASM Coordinator to manipulate an IP address pool.

CASM Coordinator: A management system which has a database to manage the overall address pools and allocate address pools to devices.

3. CASM Reference ~~A~~Aarchitecture

~~The figure below~~Figure 1 shows the reference architecture for CASM. It ~~This figure~~ covers the various possible scenarios that ~~can~~ may exist in future network.

Commentaire [Med2]: I suggest to delete this.

```
          +-------------+       +-------------+       +-------------+
          |     CASM    |       |     CASM    |       |     CASM    |
          |application 1|       |application j|       |application n|
          +-------/-----+       +-------/-----+       +-------/-----+
                  |                     |                     |
                  |                     |                     |
                  |                     |                     |
                  |                     |                     |
         +--------\---------------------\---------------------\-------+
         |    Coordinated Address Space Management System (CASM)      |
         |                       Coordinator                          |
         |    +-------------+  +-------------+  +-------------+       |
         |    |     Pool    |  |   Address   |  |   Address   |       |
         |    | Management  |  | Management  |  |  Database   |       |
         |    +-------------+  +-------------+  +-------------+       |
         |                                                            |
         +---.--------------------------.--------------------------.--+
             |                          |                          |
             |                          |                          |
             |                          |                          |
             |                          |                          |
             |                          |                          |
  +----------\---------+      +---------\---------+      +---------\------
----+
  |                    |      |                    |       |
|
  |  +-------------+   |      |  +-------------+   |       |  +------------
-+  |
  |  |     DA      |   |      |  |     DA      |   |       |  |     DA
|  |
  |  +-------------+   |      |  +-------------+   |       |  +------------
-+  |
  |                    |      |                    |       |
|
  |  +-------------+   |      |  +-------------+   |       |  +------------
-+  |
  |  |    CASM     |   |      |  |    CASM     |   |       |  |    CASM
|  |
  |  | Distributor |   |      |  | Distributor |   |       |  | Distributor
|  |
  |  +-------------+   |      |  +-------------+   |       |  +------------
-+  |
  |     Device 1       |      |     Device 2       |       |     Device m
|
  +--------------------+      +--------------------+       +----------------
----+
```

Figure 1: CASM reference architecture

Each component of CASM is introduced as below~~,~~:

1) CASM Application:

~~The CASM Application~~I ~~i~~s a functional entity which usually has the requirements of centralized address management to realize its specific upper-layer functions. In order to achieve this goal, it needs to manage, operate, and maintain the CASM Coordinator. For example, an operator or external user can manage the address pool in

Commentaire [Med3]: What does that mean ?

the CASM Coordinator, as well as access logs, address allocation records, etc.

2) CASM Coordinator:

~~The CASM Coordinator i~~Is an ~~coordinated~~ address management coordinator for the CASM Application to maintain overall address pools, addresses, address properties, etc. It maintains an address database including the overall address pools (OAP) and the address pool status (APS). CASM Applications can maintain their remaining address pools in the OAP. They can also reserve some address pools for special purposes. The address pool status is meant to reflect the current usage of address pools for different devices and services. The CASM Coordinator also has the capability to maintain the address pools to different devices dynamically.

3) CASM Device:

~~A CASM Device i~~Is responsible for distributing andor allocating addresses from local address pools received from the CASM Coordinator. CASM requires ~~has~~ two components in devices~~.~~: The first one is Device Agent (DA)~~,~~ ~~which resides in a CASM Device~~ through which the device can contact with the CASM Coordinator. ~~On behalf of the device, t~~The agent initiates the address pool allocation requests, passes the address pools to local instances, detect the availability of address pools or report the status of local address pool usage and update the address pool requests, etc. For some devices, e.g., IPv6 transition and VPN, additional routing modules are needed to update the routing table accordingly.

The CASM Distributor is another component in a CASM device. The DHCP server is a typical distributor that can assign/delegate IP addresses/prefixes to client hosts~~, and the DHCP protocol is usually used for this task~~. The address assignment procedure between the CASM Distributor and the client host is out of the scope of this document.

The device determines whether the usage status of the IP address pool resource within the device satisfies the condition. When the IP address pool resource in the device is insufficient or excessive, the device will obtain IP address pool resource request, and sends the request to the CASM Coordinator. The device receives a resource response with IP address pools allocated for it (if success), then it use these address pools to assign IP addresses to end devices~~users~~. Typical CASM Devices include BNGs, BRASes, CGNs, DHCP Servers, ~~NATs, IPv6 Transitions~~NAT64, DS-Lite AFTR, DNS Servers, etc.

The form of devices is diverse, it can be physical ~~or virtual~~, and it

Commentaire [Med4]: What is the difference between an address pool and addresses ?

Commentaire [Med5]: This is redundant with the next sentence.

Commentaire [Med6]: IP addresses in some deployments are bound to a service (internet, VoIP, IPTV, ...)

Commentaire [Med7]: How it knows this?

Mis en forme : Français (France)

Commentaire [Med8]: A device is always physical!

can be box-integrated with a control plane and a user plane, or a separated control plane remote from the box, where one or more devices share the centralized control plane. In the latter case, the control plane will manage multiple user plane devices. A number of devices that are subordinate to the control plane will jointly share the address pools to make address utilization much higher.

Commentaire [Med9]: That is ?

4. The ~~O~~overall ~~procedure~~ Procedure of CASM

1. Operators configure remaining address pools centrally in the CASM Coordinator. There are multiple address pools that can be configured. The CASM Coordinator server then divides the address pools into addressing units (AUs) which would be allocated to device agents by default.

2. The agent will initiate an AddressPool request to the CASM Coordinator. It can carry its desired size of address pool with the request, or just use a default value. The address pool size in the request is only used as a hint. The actual size of the address pool is totally determined by the CASM Coordinator. It would also carry the DA's identification and the type of the address pool.

3. The CASM Coordinator looks up remaining address pools in its local database, and then allocates (or not) a set of address pools to the DA. Each address pool has a finite lifetime.

4. The DA receives the AddressPool reply and uses it for its purpose.

5. If the lifetime of the address pool is going to expire, the DA should issue an AddressPoolRenew request to extend it, including IPv4, IPv6, port numbers, etc.

6. The AddressPoolReport module keeps monitoring and reports the usage of all current address pools for each transition mechanism. If it is running out of address pools, it can renew the AddressPoolRequest for a newly allocated one. It can also release and recycle an existing address pool if that address pool has not been used for a specific and configurable time.

7. When the connection of the CASM Coordinator is lost or it needs the status information of certain applications, it may pre-actively query the DA for its status information.

~~Currently~~In this version, the CASM system focuses on the coordination of IP address resources. This ~~Solution~~ solution ~~should~~ can be extended to handle other resources such as containers, VLAN assignments, etc. These are subject for future work.

Commentaire [Med10]: If the size is arbitrary set, this may lead to suboptimal utilization of resources.

Commentaire [Med11]: This is policy-based. You may want to add some text about this point.

Commentaire [Med12]: This assumes that DA is aware about the type to request.

I guess type is not only restricted to the address family, but may also include service type. Please clarify in the text.

Commentaire [Med13]: This is not mentioned in the figure.

Commentaire [Med14]: Does this means that a permanent session is required to be maintained?

5. CASM Interface and ~~operation~~Operation

5.1. CASM App-facing Interface

~~The CASM architecture consists of three major distinct entities: CASM Application, CASM Coordinator and network device with a device Agent (DA).~~ In order to provide address ~~space and pools~~ resource that CASM Coordinator can centrally maintain, there is an interface between CASM Applications and CASM Coordinator. The CASM Application can manage the address ~~space and pool~~resources in the CASM Coordinator, and ~~the~~ get address allocation records, logs from CASM Coordinator.

Commentaire [Med15]: Already mentioned.

Commentaire [Med16]: you may explicit examples.

5.1.1. Functional ~~requirements~~Requirements

The CASM should support the following functionality ~~for it~~ to be adopted for wide variety of use cases.

1. Address pools requirements:

A CASM system should allow ability to manage different kind of address pools. The following pools should be considered for implementation; this is not mandatory or exhaustive by any means but given here as most commonly used in networks. The CASM system should allow user-defined pools with any address objects.

Unicast address pool:

- Private IPv4 addresses/prefixes
- Public IPv4 addresses/prefixes
- IPv6 addresses/prefixes
- MAC Addresses

Multicast address pools:

- IPv4 addresses
- IPv6 addresses

Commentaire [Med17]: You may include port ranges

2. Pool management requirements

~~There should be a rich set of functionality as defined in this section for operation of a given pool.~~

Address management:

o Address allocation either as single or contiguous or noncontiguous block

o Address reservation

o Allocation logic such as mapping schemes or algorithm per pool

~~o~~

General management:

o Pool initializing, resizing, threshold markings for resource monitoring

o Pool attributes such as used to automatically create DNS record

o Pool priority for searching across different pools

o Pool fragmentation rules, such as how pool can be sub-divided

o Pool lease rules for allocation requests

5.1.2. Interface modeling requirements

There are three broad categories for CASM interface definition:

Pool management interface: Interface to external user or applications such as SDN controller to manage addresses.

Log interfaces: Interface to access log and records such as DHCP, DNS, NAT

Integration interface: Interface to address services such as DHCP, DNS, NAT

5.2. CASM device-facing Interface

In order to provide address pool manipulations between CASM Coordinator and devices, the CASM architecture calls for well-defined protocols for interfacing between them. Protocol such as ~~radius~~ Radius can be used to compatible with legacy network equipment. And in more modern network system, network device acts as NETCONF/RESTCONF server side, device like CASM Coordinator act as client side. The network device sends address pool request message carrying the requested resource information to the CASM Coordinator, the CASM Coordinator send response message to the network device, where the response message includes address pool resource information allocated to the network device, and network device receives the response message and retrieve the allocated address pool resource information carried in the response message.

Commentaire [Med18]: you may define it.

5.2.1. Functional ~~requirements~~Requirements

In order to build a complete address management system, it is important that CASM ~~should be~~is able to integrate with other address services. This ~~will~~ provides a complete solution to network operators without requiring any manual or proprietary workflows.

Mis en forme : Surlignage

DHCP server:

o Interface to initialize address pools on DHCP server

o Notification interface whenever an address lease is modified

o Interface to access address lease records from DHCP server

o Ability to store lease records and play back to DHCP server on reboot

DNS server:

o Interface to create DNS records on DNS server based on DHCP server events

NAT device:

o Interface to initialize NAT pools

o Interface to access NAT records from NAT device

o Ability to store NAT records and play back to NAT device on reboot

5.2.2. Interface ~~modeling~~ Modeling ~~requirements~~Requirements/Initial Address Pool Configuration

```
          +--------------+                          +------------------+
          |   Device     |                          |       CASM       |
          |   Agent      |                          |   Coordinator    |
          +------+-------+                          +--------+---------+
                 |                                           |
        +--------+-------+                                   |
        |1.DA start-up   |                                   |
        +---------+------+                                   |
                  |            2.Address Pool Request        |
                  |----------------------------------------->|
                  |                                          |
                  |                                 +--------+-------+
                  |                                 |  3. Check      |
                  |                                 |    address pool|
                  |                                 +--------+-------+
                  |          4.Address Pool Reply            |
                  |<-----------------------------------------|
                  |                                          |
```

Figure 2: Initial Address Pool Configuration

As shown in Figure 2, the procedure is as follows:

Commentaire [Med19]: You may add some text about authorization/mutual authentication

1. The DA checks whether there is already address pool configured in the local site when it starts up.

2. The DA will initiate Address Pool request to the CASM Coordinator. It can carry its desired size of address pool in the request, or just use a default value. The address pool size in the DA's request is only used as a hint. The actual size of the address pool is totally determined by CASM Coordinator. It will also carry the DA's identification, the type of transition mechanism and the indication of port allocation support.

3. The CASM Coordinator determines the address pool allocated for the DA based on the parameters received.

4. The CASM Coordinator sends the Address Pool Reply to the DA. It will also distribute the routing entry of the address pool automatically. In particular, if the newly received address pool can be aggregated to an existing one, the routing should be aggregated accordingly.

5.2.3. Interface ~~modeling~~ Modeling ~~requirements~~Requirements/Address Pool Status Report

```
        +--------------+                             +-----------------+
        |   Device     |                             |      CASM       |
        |   Agent      |                             |   Coordinator   |
        +------+-------+                             +---------+--------+
               |                                               |
      +--------+-------+                                       |
      |1.Monitor and   |                                       |
      |count the status|                                       |
      +--------+-------+                                       |
               |        2.Address Pool Status Report           |
               |---------------------------------------------->|
               |                                     +---------+-------+
               |                                     |  3. Record      |
               |                                     |   address pool  |
               |                                     +---------+-------+
               |       4.Address Pool Report Confirm           |
               |<----------------------------------------------|
               |                                               |
               |                                               |
```

Figure 3: Address Pool Status Report

Figure 3 illustrates the active address pool status report procedure:

1. The DA will monitor and count the usage status of the local address pool. The DA counts the address usage status in one month, one week and one day, which includes the local address, address usage ratio (peak and average values), and the port usage ratio (peak and average values).

2. The DA reports the address pool usage status to the CASM Coordinator. For example, it will report the address usage status in one day, which contains the IP address, NAT44, address list: 30.14.44.0/28, peak address value 14, average address usage ratio 90%, TCP port usage ratio 20%, UDP port usage ratio 30% and etc.

3. The CASM Coordinator records the status and compares with the existing address information to determine whether additional address pool is needed.

4. The CASM Coordinator will confirm the address pool status report request to the DA. It will keep sending the address pool status

report request to the CASM Coordinator if no confirm message is received.

5.2.4. Interface ~~modeling~~ Modeling ~~requirements~~Requirements/Address Pool Status Query

When the status of CASM Coordinator is lost or the CASM Coordinator needs the status information of the DAs, the CASM Coordinator may actively query the TD for the status information, as shown in step 1 of Figure 4. The following steps 2,3,4, and 5 are the same as the Address Pool Status Report procedure.

Mis en forme : Surlignage

```
        +---------------+                             +------------------+
        |   Device      |                             |      CASM        |
        |   Agent       |                             |   Coordinator    |
        +-------+-------+                             +---------+--------+
                |                                               |
                |                                               |
                |         1.Address Pool Status Query           |
                |<----------------------------------------------|
                |                                               |
      +--------+-------+                                        |
      |2.Monitor and   |                                        |
      |count the status|                                        |
      +--------+-------+                                        |
                |        3.Address Pool Status Report           |
                |---------------------------------------------->|
                |                                     +---------+-------+
                |                                     |  4. Record      |
                |                                     |   address pool  |
                |                                     +---------+-------+
                |       5.Address Pool Report Confirm           |
                |<----------------------------------------------|
                |                                               |
                |                                               |
```

Figure 4: Address Pool Status Query

5.2.5. Interface modeling requirements/Address Exhaustion

When the addresses used by the DA reaches a certain usage threshold, the DA will renew the address pool request to the CASM Coordinator for an additional address pool. The procedure is the same as the initial address pool request.

5.2.6. Interface modeling requirements / Address Pool Release

```
        +---------------+                             +------------------+
        |   Device      |                             |       CASM       |
        |   Agent       |                             |    Coordinator   |
        +------+--------+                             +--------+---------+
               |                                               |
      +--------+-------+                                       |
      |1.Address pools |                                       |
      |  not used for a|                                       |
      |   long time    |                                       |
      +--------+-------+                                       |
               |        2.Address Pool Release Request         |
               |---------------------------------------------->|
               |                                      +--------+-------+
               |                                      |3. Update       |
               |                                      |   address pool |
               |                                      |   database     |
               |                                      +--------+-------+
               |       4.Address Pool Release Notification     |
               |<----------------------------------------------|
      +--------+-------+                                       |
      |5. Reduce       |                                       |
      |  address pool  |                                       |
      +--------+-------+                                       |
               |         6.Address Pool Release Confirm        |
               |---------------------------------------------->|
               |                                               |
               |                                               |
```

Figure 5: Address Pool Release

Figure 5 illustrates the address pool release procedure:

1. The counting module in the DA checks if the usage threshold of address pool reaches a certain condition;

2. The DA sends the address pool release request to the CASM Coordinator to ask the release of those addresses;

3. The CASM Coordinator updates the local address pool information to add the new addressed released;

4. The CASM Coordinator notifies the TD that the addresses have been release successfully;

5. The DA will update the local address pool. If no Address Pool Release Notification is received, the DA will repeat step 2;

6. Optionally, the DA confirms with the CASM Coordinator that the address pool has been released successfully.

6. Services SDN Management Use Cases

Commentaire [Med20]: What is the motivation fro having this use case? Are there unique requirements that can be derived from it?

```
                            -------------
                           |     CASM    |
                           | Application |
                            -------------
                                  :
                         ------------------
                        |     Provider     |
                        |   Orchestrator   |
                        |                  |
                        .------------------.
                     .            :          .
                   .              :           .
             ------------     ------------     ------------
            |            |   |            |   |            |
            | Controller |   | Controller |   | Controller |
            |            |   |            |   |            |
             ------------     ------------     ------------
                 :              .       .             :
                 :            .           .           :
                 :          .               .         :
             ---------     ---------   ---------     ---------
            | Network |   | Network | | Network |   | Network |
            | Element |   | Element | | Element |   | Element |
             ---------     ---------   ---------     ---------
```

Figure 6: L3 and L2 Services Orchestration

Network Operators need to manage addressing of undelay network elements in order to build end-to-end services and private or public clouds. So address management of customer ~~equipments~~equipment, provider edges, but also of virtual machines, virtual functions and overlay networks is a very important task. In general the SDN Orchestrators and other management systems must coordinate addressing schemes to ensure network operation. There is need for one address management system that would meet the requirements of such a network deployment. The SDN Orchestrator manages IPv4, IPv6 addresses and also MAC addresses to assign to network interfaces in order to install end-to-end services, and this task can be achieved by the CASM coordination.

A typical use case is the application to the Service provisioning of L3VPN and L2VPN by the SDN orchestration level. For example the architecture presented in [RFC8309] and, more in general in every SDN architecture, could be integrated with CASM. It is important to mention also the possibility of Multi-Provider services, and in this case the two CASM coordinators of the two involved Providers should synchronize. The following Figure shows how CASM Application can communicate with both the Network Operator Orchestrator and, in case of Multi-Provider Service, with another Network Operator Orchestrator too.

7. Security Considerations

Commentaire [Med21]: There are plenty security considerations that need to be documented: mutual authentication, address exhaustion, …

8. Acknowledgements

N/A.

9. References

9.1. Normative References

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Commentaire [Med22]: These are not normative for this document. Should be moved to 9.2

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