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Coordinated Address Space Management architecture

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Abstract

IP addresses work as a basic element for providing broadband network

services. However, the increase in number, diversity and complexity

of modern network devices and services creates 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. 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.

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Li, et al. Expires December 30, 2018 [Page 1]

Internet-Draft Address Pool Management June 2018

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Table of Contents

1. Introduction . . . . . . . . . . . . . . . . . . . . . . . . 3

2. Terminology . . . . . . . . . . . . . . . . . . . . . . . . . 4

3. CASM Reference architecture . . . . . . . . . . . . . . . . . 4

4. The overall procedure of CASM . . . . . . . . . . . . . . . . 7

5. CASM Interface and operation . . . . . . . . . . . . . . . . 8

5.1. CASM App-facing Interface . . . . . . . . . . . . . . . . 8

5.1.1. Functional requirements . . . . . . . . . . . . . . . 8

5.1.2. Interface modeling requirements . . . . . . . . . . . 9

5.2. CASM device-facing Interface . . . . . . . . . . . . . . 9

5.2.1. Functional requirements . . . . . . . . . . . . . . . 10

5.2.2. Interface modeling requirements/Initial Address Pool

Configuration . . . . . . . . . . . . . . . . . . . . 10

5.2.3. Interface modeling requirements/Address Pool Status

Report . . . . . . . . . . . . . . . . . . . . . . . 12

5.2.4. Interface modeling requirements/Address Pool Status

Query . . . . . . . . . . . . . . . . . . . . . . . . 13

5.2.5. Interface modeling requirements/Address Exhaustion . 13

5.2.6. Interface modeling requirements / Address Pool

Release . . . . . . . . . . . . . . . . . . . . . . . 14

6. Services SDN Management Use Cases . . . . . . . . . . . . . . 15

7. Security Considerations . . . . . . . . . . . . . . . . . . . 16

8. Acknowledgements . . . . . . . . . . . . . . . . . . . . . . 16

9. References . . . . . . . . . . . . . . . . . . . . . . . . . 16

9.1. Normative References . . . . . . . . . . . . . . . . . . 16

Li, et al. Expires December 30, 2018 [Page 2]

Internet-Draft Address Pool Management June 2018

9.2. Informative References . . . . . . . . . . . . . . . . . 17

Authors' Addresses . . . . . . . . . . . . . . . . . . . . . . . 17

1. Introduction

The address space management is an integral part of any network

management solution. However, the increase in number, diversity and

complexity of modern network devices and services creates

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 the 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

approach.

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 addresses, Such a

system should be capable of automating the address scheduling

process. 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 address management system. This system is

called Coordinated 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 address

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.

Above is one example of use case, 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,

Li, et al. Expires December 30, 2018 [Page 3]

Internet-Draft Address Pool Management June 2018

which can be used in multiple use cases. With this approach,

operators do not need to configure the address pools one by one

manually 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: A device agent within the device, which contacts with CASM

Coordinator to manipulate address pool

CASM Coordinator: A management system which has a database and manages

the overall address pools and allocate address pools to devices.

3. CASM Reference architecture

The figure below shows the reference architecture for CASM. This

figure covers the various possible scenarios that can exist in future

network.

Li, et al. Expires December 30, 2018 [Page 4]

Internet-Draft Address Pool Management June 2018

+-------------+ +-------------+ +-------------+

| CASM | | CASM | | CASM |

|application 1| |application j| |application n|

+------/------+ +------/------+ +------/------+

| | |

| | |

| | |

| | |

+-------\---------------------\---------------------\-------+

| Coordinated Address Space Management System (CASM) |

| Coordinator |

| +-------------+ +-------------+ +-------------+ |

| | Pool | | Address | | Address | |

| | Management | | Management | | Database | |

| +-------------+ +-------------+ +-------------+ |

| |

+---.-------------------------.--------------------------.--+

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+----------\--------+ +---------\---------+ +--------\----------+

| | | | | |

| +-------------+ | | +-------------+ | | +-------------+ |

| | 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 is 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

Li, et al. Expires December 30, 2018 [Page 5]

Internet-Draft Address Pool Management June 2018

the CASM Coordinator, as well as access log, address allocation

records, etc.

2) CASM Coordinator

The CASM Coordinator is a 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 to reflect the current usage of

address pools for different devices. The CASM Coordinator also has

the capability to maintain the address pools to different devices

dynamically.

3) CASM Device

A CASM Device is responsible for distributing or allocating addresses

from local address pools received from the CASM Coordinator. CASM

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, 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 IP addresses 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, then it can use these

address pools to assign IP addresses to end users. Typical CASM

Devices include BNGs, BRASes, CGNs, DHCP Servers, NATs, IPv6

Transitions, DNS Servers, etc.

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

can be box-integrated with a control plane and a user plane, or a

Li, et al. Expires December 30, 2018 [Page 6]

Internet-Draft Address Pool Management June 2018

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.

4. The overall 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 a set of address pools to the

DA. Each address pool has a 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, the CASM system focuses on the coordination of IP address

resources. This Solution should be extended to handle containers,

VLAN assignments, etc. These are subject for future work.

Li, et al. Expires December 30, 2018 [Page 7]

Internet-Draft Address Pool Management June 2018

5. CASM Interface and 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 in the CASM Coordinator, and the

get address allocation records, logs from CASM Coordinator.

5.1.1. Functional requirements

The CASM should support 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:

o Private IPv4 addresses

o Public IPv4 addresses

o IPv6 addresses

o MAC Addresses

Multicast address pool:

o IPv4 address

o IPv6 address

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:

Li, et al. Expires December 30, 2018 [Page 8]

Internet-Draft Address Pool Management June 2018

o Address allocation either as single or 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 interface: 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 device, the CASM architecture calls for well-defined

protocols for interfacing between them. Protocol such as 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.

Li, et al. Expires December 30, 2018 [Page 9]

Internet-Draft Address Pool Management June 2018

5.2.1. Functional requirements

In order to build a complete address management system, it is

important that CASM should be able to integrate with other address

services. This will provide a complete solution to network operators

without requiring any manual or proprietary workflows.

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 requirements/Initial Address Pool

Configuration

Li, et al. Expires December 30, 2018 [Page 10]

Internet-Draft Address Pool Management June 2018

+--------------+ +-----------------+

| 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:

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.

Li, et al. Expires December 30, 2018 [Page 11]

Internet-Draft Address Pool Management June 2018

5.2.3. Interface modeling 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

Li, et al. Expires December 30, 2018 [Page 12]

Internet-Draft Address Pool Management June 2018

report request to the CASM Coordinator if no confirm message is

received.

5.2.4. Interface modeling 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 2,3,4,5 are the same as the Address

Pool Status Report procedure.

+--------------+ +-----------------+

| 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.

Li, et al. Expires December 30, 2018 [Page 13]

Internet-Draft Address Pool Management June 2018

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;

Li, et al. Expires December 30, 2018 [Page 14]

Internet-Draft Address Pool Management June 2018

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

-------------

| CASM |

| Application |

-------------

:

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| Provider |

| Orchestrator |

| |

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. : .

. : .

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| | | | | |

| 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, 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.

Li, et al. Expires December 30, 2018 [Page 15]

Internet-Draft Address Pool Management June 2018

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

8. Acknowledgements

N/A.

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Li, et al. Expires December 30, 2018 [Page 16]

Internet-Draft Address Pool Management June 2018

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Li, et al. Expires December 30, 2018 [Page 17]

Internet-Draft Address Pool Management June 2018

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Li, et al. Expires December 30, 2018 [Page 18]