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An Intent-based Framework of Network Services Autonomic Deployment and  
Management  
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## Abstract

This document introduces an intent-based framework for network services autonomic deployment and management. It autonomically deploys network services that require customized combinations of network resources and dynamically manage these resources throughout their lifecycle. The framework leverages the GeneRic Autonomic Signaling Protocol (GRASP) to facilitate the dynamic exchange of resource management signals among autonomic nodes, thereby enabling coordinated and consistent operations within an autonomic network domain. This framework is generic and applicable to most types of network resources.

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## 1. Introduction

Traditionally, IP networks are based on the best-efforts model. The IP layer does not reserve resources for upper-layer applications. However, more and more emerging applications that require quality services, such as video, VR, AR, and so on. They need supports from steady network resources, such as bandwidth, queue, memory, priority, computational resources, etc. These network applications are strongly based on the availability and stability of network resources. To enable these resource-based applications and services, IETF have developed many resource reservation mechanisms, such as RSVP [RFC2205] that is mainly to reserve bandwidth only and path-oriented. However, most of them are mainly for reservation during the deployment only and are rigid for dynamic adjustment. Furthermore, most of them are dedicated for a certain type of network

resources.

However, the requirements for network resources from various end users are highly diverse and dynamic. Mechanisms that enable trustworthy users or user nodes, not only rigid network management plane, to dynamically and autonomically deploy and manage their customized network services are urgently needed. Yet, designing such mechanisms in wide networks is quite challenge due to their architecture and inherent complexity. It is much more feasible to design such mechanisms within autonomic networks, giving more secured and extensible autonomic network infrastructure.

This document introduces an intent-based framework for network services autonomic deployment and management. Within autonomic networks, every nodes are secured and trustworthy, giving the secure precondition provided by the Autonomic Control Plane (ACP) [RFC8994] and the Bootstrapping Remote Secure Key Infrastructure (BRSKI) [RFC8995]. These nodes, representing the applications or end users on them, can describe their customized requirements for network resources into a service intent, which are described in [RFC7575]. Then, the RM ASAs, defined in Section 3 this document, would breakdown these requirements and dynamically dispatches network resources, by using the GeneRIC Autonomic Signaling Protocol (GRASP) [RFC8990] to dynamically negotiate among the autonomic nodes.

This framework is generic and applicable to most, if not all, of types of network resources. It can be easily extended to support any newly-appear network resources. It can be used, but no limited, in below network scenarios:

- \* Quality transmission. The quality could means guaranteed bandwidth, or jitter, etc. In order guarantee the quality of network transmission, the network should reserve transmission resource, particularly bandwidth or queues, on a selected path from the ingress to the egress node. The dynamic resource dispatching mechanism should ensure the consistent of reserved resources on all the nodes in this path, particularly, when dynamic changes are operated on this path.
- \* Difference transmission. The network may provide different transmission by putting the user packets into different processes that have different resources, such as bandwidth, queue length, priority, etc. The results would be different user experience in delay and jitter, or even packet lose rate.

- \* In-network cache/storage. The network may provide in-network cache or storage by memory in the network devices or attached devices. The idle memory space is the resource that need to be request and managed. The location or distance of the memory is also relevant to user experience.
- \* Computing offload or in-network computing. More and more spare computational resources are from network providers. They may be idle computational cycles on the network devices or deployed computational servers. The occupation of these computational resources is time-sensitive. Also, the location or distance of the computational resource is relevant to user experience. Computing resource in the transmission path can also executes computational tasks within network elements during data transmission.
- \* Information provision. In some scenarios, network may be the best information provider. It may be the information are from or generated by network itself. Or the network has the best location to provide the information.
- \* Multiple resource management in data centers. Within data centers, autonomic resource management shall integrate traffic, storage, and computing power to optimize performance and efficiency. It shall dynamically allocate network bandwidth, computational CPU/GPU cores, and storage I/O based on real-time demand, ensuring balanced workloads and minimal latency. This holistic approach prevents bottlenecks, maximizes hardware utilization, and supports scalable, reliable cloud services.

This document defines an Autonomic Resource Management Objective in Section 5. Three new corresponding registries are defined in Section 7.

## 2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

## 3. Terminology & Abbreviations

This document builds upon and extends the previous terminology defined in [RFC7575] and [RFC8993].

**Network Service:** a customizable composite of network resources, defined by trustworthy users or network management plane to fulfill specific operational requirements through the orchestrated combination of underlying infrastructure elements.

**Service Intent:** the declarative expression of requirements that specifies the desired characteristics, constraints, and objectives for a network service, serving as the input for resource dispatching without detailing implementation mechanisms.

**RM ASA:** the Resource Manager ASA on autonomic nodes. It manages the local resources on the node, such as bandwidth, queue, memory, priority, computational resources, etc. The RM ASA communicate with other counterpart RM ASAs in order to dynamically dispatch network resources within the autonomic network domain. This document assumes all autonomic nodes have a RM ASA.

**Service Initiator:** the autonomic node that initiates and manages a network service. It receives and processing a Service Intent by parsing the intent into discrete resource requests with associated constraints. It subsequently initiates resource requests and dynamically adjusts these resources of this network service through its RM ASA by negotiating with relevant network elements.

**Service Responder:** the autonomic node that responses to the requests from the Service Initiator. It receives the requests through its RM ASA, checks or operates on its local resources, and responds the results to the Service Initiator. Typically, a network service MAY involve multiple Service Responders. The consistency among them is the responsibility of the Service Initiator.

#### 4. A Generic Auto-deployment Mechanism of Resource-based Network Services

This section describes the generic procedures of autonomic deployment and management of the resource-based network services, as Figure1 shows. The format of service intent is defined in [draft-zhu-anima-service-intent]. The prepositive operation that input/setup/initiate the service intent is out of document scope. The detailed implementation or internal algorithms of the Resource Manager ASAs are out of scope. The specific details that depend on certain network services or certain type of network resources are also out of scope. The modification on a service intent may trigger the dynamic service changes.

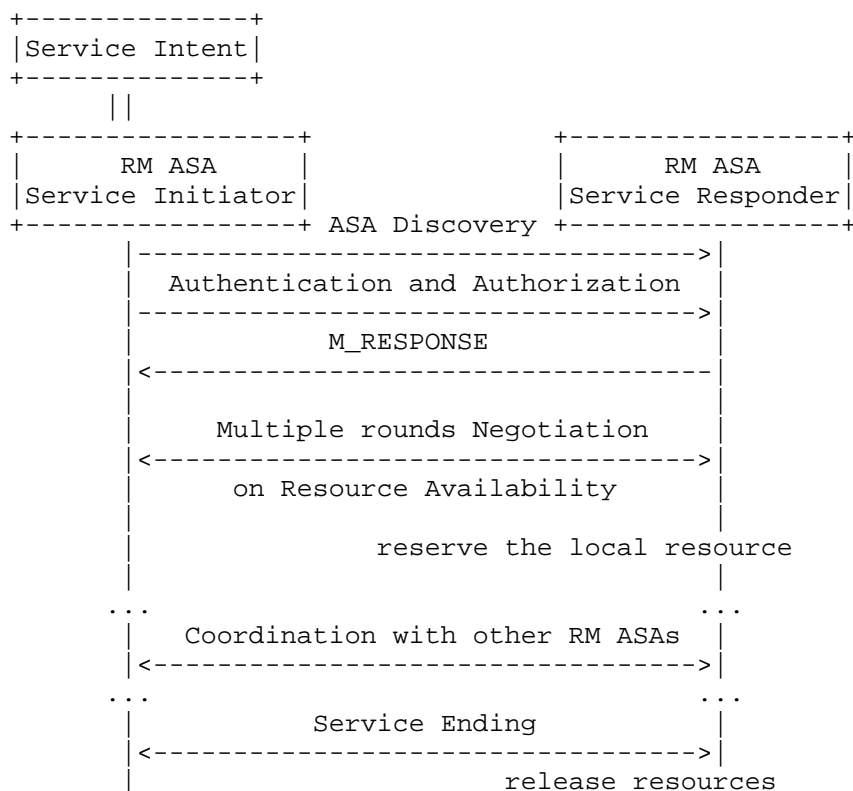


Figure-1: generic procedures of autonomic deployment and management

#### 4.1. Service Intent initiates RM ASA for Service Deployment

On the node that a service intent is given, the service intent that describes the customized network resource requirements as stipulated by trustworthy users or network management systems, undergoes a comprehensive decomposition process. This process translates the high-level intent into granular, specific requirements across various categories of network resources, including but not limited to transmission bandwidth, data storage capacity, computational power, and information accessibility/provision. Following this decomposition, the RM ASA on the Service Initiator node is activated. The primary function of this RM ASA is to dynamically orchestrate, allocate, and dispatch the required network resources in real-time, ensuring that the service intent is fulfilled efficiently and adaptively throughout its lifecycle.

#### 4.2. Discover RM ASAs on Proper Service Responders

The Service Initiator MAY first discover the relevant network nodes according to the resource requirements described in the service intent in order to reduce the node range of sending GRASP Discovery message. It may be all the nodes on a giving path or nodes that have idle resource available for giving service condition, etc. The node discover methods can be pre-configured, outbound discover, path detection, etc.

The Service Initiator SHOULD send out a GRASP Discovery message that contains a Resource Manager Objective option defined in Section 5, in which the network service is described. The Discovery message SHOULD send to the reduced range nodes, by abovementioned mechanism, or all nodes within the AN domain.

A RM ASA that receives the Discovery message with the Resource Manager Objective option SHOULD check its satisfaction against the service description. If meet, the node is a proper Service Responder. It SHOULD respond a GRASP Response message back to the Service Initiator.

Defined in the section 2.5.5.1 of [RFC8990], the Discovery message MAY combine with the below negotiation process, if the rapid negotiation function has been enabled network wide. If the rapid negotiation function has been disabled, the process would fall back to the normal discovery-only process.

#### 4.3. Authentication and Authorization

In principle, any operations on resources MUST be authorized. The Service Responder SHOULD check the authentication of the Service Initiator and the authorization information for the operation it requests. This document assumes all autonomic nodes within the AN domain have been authenticated and their requested operations are authorized, giving the Autonomic Control Plane (ACP) [RFC8994] and the Bootstrapping Remote Secure Key Infrastructure (BRSKI) [RFC8995] has provided the secure environment for this mechanism.

#### 4.4. Negotiate Resource with Service Responder

After the discovery step, the RM ASA on the Service Initiator sends a GRASP Request message with a Resource Manager Objective option, in which the value of the requested resource is indicated.

When the RM ASA on a Service Responder receives a subsequent Request message, it SHOULD conduct a GRASP negotiation sequence, using Negotiate, Confirm Waiting, and Negotiation End messages as

appropriate. The Negotiate messages carry a Resource Manager Objective option, which will indicate the resource type and value offered to the requesting RM ASA.

During the negotiation, the RM ASA on the Service Responder will decide at each step how much resource can be offered. That decision, and the decision to end the negotiation, are implementation choices. A resource shortage on the Service Responder may cause it to indicate the existing available value within a Resource Manager Objective option back to the Service Initiator. The Service Initiator might decide whether to accept the request of the resource. If not, the RM ASA on the Service Initiator MAY terminate the negotiation via Negotiation End messages.

Upon completion of the negotiation, the Service Responder reserves its local resources. The Service Initiator may use the negotiated resource after receiving synchronization message without further messages.

Normally, a network service SHALL have one service initiator within an autonomic network domain. It is the Service Initiator's responsibility to manage the service and coordinate among multiple Service Responders to ensure the consistent of reserved resources.

#### 4.5. Change Reserved Resources

After the process of automatic resource management mechanism, RM ASAs are allowed to change and negotiate the resource requirements. In the lifetime of network services, there may be many reasons that the service has to be changed upon with its reserved resources. Resource Manager ASA needs to be able to handle resource changes in a timely manner to meet service requirements.

During the renegotiation process, RM ASA on the Service Initiator resends the service's resource requirements by using Resource Manager GRASP Objective. RM ASA on the Service Responder receives the resource negotiation message and makes the determination. If the resource requirements are lower than those allocated or/and less lifetime than previous, the Service Responder SHOULD directly confirm the information and release the excess resources. If more resources or lifetime are required, RM ASA on the Service Responder SHOULD treat it as a brand-new request and make decision or further negotiation. The bottom line is the Service Responder MUST allow the Service Initiator fall back to previous allocated resource, both on volume and lifetime.

RM ASAs on the Service Responders MUST NOT change existing resource allocation until the new negotiation on resource changes is complete.



#### 4.6. Releasing Resources during Service Ending

After the service is completed or expired, the reserved network resources MUST be released so that network resources can be used more efficiently. If the service lifetime expires, the Service Responder MUST release its local resources and MAY send a Synchronization message to the Service Initiator to notify the state change of its local resources. If the Service Initiator wants to end the service before the service lifetime expires, the Service Initiator MUST send a negotiation message to the Service Responders to request the network resource to be changed to zero. Upon completion of the negotiation, the Service Responder releases the resources occupied by the service.

#### 5. Autonomic Resource Management Objectives

This section defines the GRASP technical objective options that are used to support autonomic resource management. Resource Manager GRASP Objective allows multiple types of resources to be requested simultaneously.

The Resource Manager Objective option is a GRASP Objective option conforming to the GRASP specification [RFC8990]. Its name is "Resource Manager", and it carries the following data items as its value: the resource value. Since GRASP is based on CBOR (Concise Binary Object Representation) [RFC8949], the format of the Resource Manager Objective option is described in the Concise Data Definition Language (CDDL) [RFC8610] as follows:

```
objective = ["Resource Manager", objective-flags, loop-count,  
?objective-value]
```

```
objective-name = "Resource Manager"
```

```
objective-flags = uint .bits objective-flag ; as in the GRASP  
specification
```

```
loop-count = 0..255 ; as in the GRASP specification
```

The 'objective-value' field expresses the actual value of a negotiation or synchronization objective. So a new objective-value named autonomic-network-service-value is defined for Network Service Auto-deployment as follows. The autonomic node can know that it is serving Network Service Auto-deployment according to the objective-value after receiving the GRASP message. The 'objective value' contains two parts, one represents the information of the service itself, and the other represents the requirements of resources.

objective-value = autonomic-network-service-value; An autonomic-network-service-value is defined as Figure-2.

```
autonomic-network-service-value =  
  [  
    [  
      service-type,  
      service-id,  
      service-lifetime,  
      service-tag  
    ],  
    [  
      *resource-requirement-pair  
    ]  
  ]
```

Figure-2: Format of autonomic-network-service-value

service-type = 0..7

service-id = uint

service-lifetime = 0..4294967295 ; in milliseconds

service-tag = [ \*service-tag-info]

The combination service-type and the service-id MUST uniquely represent a network service within the network. The uniqueness of the combination service-type and the service-id SHOULD be guaranteed by an allocation mechanism that is out of scope of this document.

The allocation of resources MUST specify the lifetime. The service-lifetime represents the usage time of the resources required by the service.

The service-tag contains other information that describes the service. This information is not necessary, but will affect the policy for RM ASA resource reservation.

The resource-requirement-pair describes the resource requirements and it is defined as Figure-3. Resource requirements of different types can be described in an objective option. The Resource Manager objective option supports multi-faceted resource requirements and negotiation. These resource requirements are all in pairs, described by resource type and resource value.

```
resource-requirement-pair =  
    [  
        resource-type,  
        resource-value  
    ]
```

Figure-3: Format of resource-requirement-pair

resource-type = 0..7

resource-value = uint

## 6. Security Considerations

It complies with GRASP security considerations. Relevant security issues are discussed in [RFC8990]. The preferred security model is that devices are trusted following the secure bootstrap procedure [RFC8995] and that a secure Autonomic Control Plane (ACP) [RFC8994] is in place.

## 7. IANA Considerations

This document defines a new GRASP Objective option names: "Resource Manager" which need to be added to the "GRASP Objective Names" registry defined by [RFC8990]. And this document defines a new registry tables "service-type" and "resource-type" under the "Resource Manager" GRASP Objective. The following subsections describe the new parameters.

### 7.1. Service type

IANA has set up the "service-type" registry, which contains 4-bit value. The service-type defines the type of service which is used to describe the type of resource requirements.

- \* 0 : Transmission Service
- \* 1 : Computing Service

### 7.2. Resource Type

IANA has set up the "resource-type" registry, which contains 4-bit value.

- \* 0 : bandwidth
- \* 1 : queue

- \* 2 : memery
- \* 3 : priority
- \* 4 : cache
- \* 5 : computing

## 8. Acknowledgements

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