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RADIUS Extensions for IP Port Configuration and Reporting
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Abstract

This document defines three new RADIUS attributes. For devices that implement IP port ranges, these attributes are used to communicate with a RADIUS server in order to configure and report IP transport ports, as well as mapping behavior for specific hosts. This mechanism can be used in various deployment scenarios such as Carrier-Grade NAT, IPv4/IPv6 translators, Provider WLAN Gateway, etc. This document defines a mapping between some RADIUS attributes and IPFIX Information Element Identifiers.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

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[1.](#) Introduction

In a broadband network, customer information is usually stored on a RADIUS server [[RFC2865](#)]. At the time when a user initiates an IP connection request, if this request is authorized, the RADIUS server will populate the user's configuration information to the Network Access Server (NAS), which is often referred to as a Broadband Network Gateway (BNG) in broadband access networks. The Carrier-Grade NAT (CGN) function may also be implemented on the BNG. Within this document, the CGN may perform NAT44 [[RFC3022](#)], NAT64 [[RFC6146](#)], or Dual-Stack Lite AFTR [[RFC6333](#)] function. In such case, the CGN IP transport port (e.g., TCP/UDP port) mapping(s) behavior(s) can be part of the configuration information sent from the RADIUS server to the NAS/BNG. The NAS/BNG may also report to the RADIUS Server the IP port mapping behavior applied by the CGN to a user session to the RADIUS server, as part of the accounting information sent from the NAS/BNG to a RADIUS server.

When IP packets traverse the CGN, it performs mapping on the IP transport (e.g., TCP/UDP) source port as required. An IP transport source port, along with source IP address, destination IP address, destination port and protocol identifier if applicable, uniquely identify a mapping. Since the number space of IP transport ports in CGN's external realm is shared among multiple users assigned with the same IPv4 address, the total number of a user's simultaneous IP mappings is likely to be subject to port quota (see [Section 5 of \[RFC6269\]](#)).

The attributes defined in this document may also be used to report the assigned port range in some deployments such as Provider WLAN [[I-D.gundavelli-v6ops-community-wifi-svcs](#)]. For example, a visiting host can be managed by a CPE (Customer Premises Equipment) which will need to report the assigned port range to the service platform. This is required for identification purposes (see TR-146 [[TR-146](#)] for more details).

This document proposes three new attributes as RADIUS protocol's extensions, and they are used for separate purposes as follows:

1. IP-Port-Limit-Info: This attribute may be carried in a RADIUS Access-Accept, Access-Request, Accounting-Request or CoA-Request packet. The purpose of this attribute is to limit the total number of IP source transport ports allocated to a user, associated with one or more IPv4 or IPv6 addresses.
2. IP-Port-Range: This attribute may be carried in a RADIUS Accounting-Request packet. The purpose of this attribute is for an address sharing device (e.g., a CGN) to report to the RADIUS server the range of IP source transport ports that have been allocated or deallocated for a user. The port range is bound to an external IPv4 address.
3. IP-Port-Forwarding-Map: This attribute may be carried in RADIUS Access-Accept, Access-Request, Accounting-Request or CoA-Request packet. The purpose of this attribute is to specify how an IP internal source transport port together with its internal IPv4 or IPv6 address are mapped to an external source transport port along with the external IPv4 address.

IPFIX Information Elements [[RFC7012](#)] can be used for IP flow identification and representation over RADIUS. This document provides a mapping between some RADIUS TLVs and IPFIX Information Element Identifiers. A new IPFIX Information Element is defined by this document (see [Section 3.2.2](#)).

IP protocol numbers (refer to [[ProtocolNumbers](#)]) can be used for identification of IP transport protocols (e.g., TCP, UDP, DCCP, and SCTP) that are associated with some RADIUS attributes.

This document focuses on IPv4 address sharing. IPv6 prefix sharing mechanisms (e.g., NPTv6) are out of scope.

2. Terminology

This document makes use of the following terms:

- o IP Port: refers to IP transport port (e.g., TCP port number, UDP port number).
- o IP Port Type: refers to the IP transport protocol as indicated by the IP transport protocol number, refer to (refer to [[ProtocolNumbers](#)])
- o IP Port Limit: denotes the maximum number of IP ports for a specific IP port type, that a device supporting port ranges can use when performing port number mappings for a specific user/host.

Note, this limit is usually associated with one or more IPv4/IPv6 addresses.

- o IP Port Range: specifies a set of contiguous IP ports, indicated by the lowest numerical number and the highest numerical number, inclusively.
- o Internal IP Address: refers to the IP address that is used by a host as a source IP address in an outbound IP packet sent towards a device supporting port ranges in the internal realm. The internal IP address may be IPv4 or IPv6.
- o External IP Address: refers to the IP address that is used as a source IP address in an outbound IP packet after traversing a device supporting port ranges in the external realm. This document assumes that the external IP address is an IPv4 address.
- o Internal Port: is an IP transport port, which is allocated by a host or application behind an address sharing device for an outbound IP packet in the internal realm.
- o External Port: is an IP transport port, which is allocated by an address sharing device upon receiving an outbound IP packet in the internal realm, and is used to replace the internal port that is allocated by a user or application.
- o External realm: refers to the networking segment where external IP addresses are used as source addresses of outbound packets forwarded by an address sharing device.
- o Internal realm: refers to the networking segment that is behind an address sharing device and where internal IP addresses are used.
- o Mapping: denotes a relationship between an internal IP address, internal port and the protocol, and an external IP address, external port, and the protocol.
- o Address sharing device: a device that is capable of sharing an IPv4 address among multiple users. A typical example of this device is a CGN, CPE, Provider WLAN Gateway, etc.

3. Extensions of RADIUS Attributes and TLVs

These three new attributes are defined in the following sub-sections:

1. IP-Port-Limit-Info Attribute
2. IP-Port-Range Attribute

3. IP-Port-Forwarding-Map Attribute

All these attributes are allocated from the RADIUS "Extended Type" code space per [\[RFC6929\]](#).

These attributes and their embedded TLVs (refer to [Section 3.2](#)) are defined with globally unique names and follow the guideline in [Section 2.7.1 of \[RFC6929\]](#).

In all the figures describing the RADIUS attributes and TLV formats in the following sub-sections, the fields are transmitted from left to right.

3.1. Extended Attributes for IP Ports

3.1.1. IP-Port-Limit-Info Attribute

This attribute is of type "TLV" as defined in the RADIUS Protocol Extensions [\[RFC6929\]](#). It contains some sub-attributes and the requirement is as follows:

- o The IP-Port-Limit-Info Attribute MAY contain the IP-Port-Type TLV (see [Section 3.2.1](#)).
- o The IP-Port-Limit-Info Attribute MUST contain the IP-Port-Limit TLV (see [Section 3.2.2](#)).
- o The IP-Port-Limit-Info Attribute MAY contain the IP-Port-Ext-IPv4-Addr TLV (see [Section 3.2.3](#)).

The IP-Port-Limit-Info Attribute specifies the maximum number of IP ports as indicated in IP-Port-Limit TLV, of a specific IP transport protocol as indicated in IP-Port-Type TLV, and associated with a given IPv4 address as indicated in IP-Port-Ext-IPv4-Addr TLV for an end user.

Note that when IP-Port-Type TLV is not included as part of the IP-Port-Limit-Info Attribute, the port limit applies to all IP transport protocols.

Note also that when IP-Port-Ext-IPv4-Addr TLV is not included as part of the IP-Port-Limit-Info Attribute, the port limit applies to all the IPv4 addresses managed by the address sharing device, e.g., a CGN or NAT64 device.

The IP-Port-Limit-Info Attribute MAY appear in an Access-Accept packet. It MAY also appear in an Access-Request packet as a

preferred maximum number of IP ports indicated by the device supporting port ranges co-located with the NAS, e.g., a CGN or NAT64.

The IP-Port-Limit-Info Attribute MAY appear in a CoA-Request packet.

The IP-Port-Limit-Info Attribute MAY appear in an Accounting-Request packet.

The IP-Port-Limit-Info Attribute MUST NOT appear in any other RADIUS packet.

The format of the IP-Port-Limit-Info Attribute is shown in Figure 1.

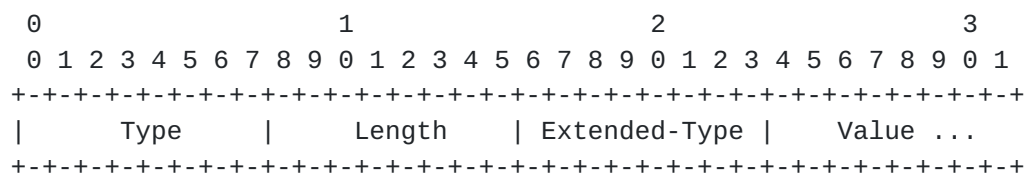


Figure 1

Type

241 (To be confirmed by IANA).

Length

This field indicates the total length in bytes of all fields of this attribute, including the Type, Length, Extended-Type, and the entire length of the embedded TLVs.

Extended-Type

TBD1.

Value

This field contains a set of TLVs as follows:

IP-Port-Type TLV

This TLV contains a value that indicates the IP port type.
Refer to [Section 3.2.1](#).

IP-Port-Limit TLV

This TLV contains the maximum number of IP ports of a specific IP port type and associated with a given IPv4 address for an

end user. This TLV MUST be included in the IP-Port-Limit-Info Attribute. Refer to [Section 3.2.2](#). This limit applies to all mappings that can be instantiated by an underlying address sharing device without soliciting any external entity. In particular, this limit does not include the ports that are instructed by an AAA server.

IP-Port-Ext-IPv4-Addr TLV

This TLV contains the IPv4 address that is associated with the IP port limit contained in the IP-Port-Limit TLV. This TLV is optionally included as part of the IP-Port-Limit-Info Attribute. Refer to [Section 3.2.3](#).

IP-Port-Limit-Info Attribute is associated with the following identifier: 241.Extended-Type(TBD1).

[3.1.2](#). IP-Port-Range Attribute

This attribute is of type "TLV" as defined in the RADIUS Protocol Extensions [[RFC6929](#)]. It contains some sub-attributes and the requirement is as follows:

- o The IP-Port-Range Attribute MAY contain the IP-Port-Type TLV (see [Section 3.2.1](#)).
- o The IP-Port-Range Attribute MUST contain the IP-Port-Alloc TLV (see [Section 3.2.8](#)).
- o For port allocation, the IP-Port-Range Attribute MUST contain both the IP-Port-Range-Start TLV (see [Section 3.2.9](#)) and the IP-Port-Range-END TLV (see [Section 3.2.10](#)). For port deallocation, the IP-Port-Range Attribute MAY contain both of these two TLVs; if the two TLVs are not included, it implies that all ports that were previously allocated are now all deallocated.
- o The IP-Port-Range Attribute MAY contain the IP-Port-Ext-IPv4-Addr TLV (see [Section 3.2.3](#)).
- o The IP-Port-Range Attribute MAY contain the IP-Port-Local-Id TLV (see [Section 3.2.11](#)).

The IP-Port-Range Attribute contains a range of contiguous IP ports. These ports are either to be allocated or deallocated depending on the Value carried by the IP-Port-Alloc TLV.

If the IP-Port-Type TLV is included as part of the IP-Port-Range Attribute, the port range is associated with the specific IP

transport protocol as specified in the IP-Port-Type TLV, but otherwise is for all IP transport protocols.

If the IP-Port-Ext-IPv4-Addr TLV is included as part of the IP-Port-Range Attribute, the port range as specified is associated with IPv4 address as indicated, but otherwise is for all IPv4 addresses by the address sharing device (e.g., a CGN device) for the end user.

This attribute can be used to convey a single IP transport port number; in such case the Value of the IP-Port-Range-Start TLV and the IP-Port-Range-End TLV, respectively, contain the same port number.

The information contained in the IP-Port-Range Attribute is sent to RADIUS server.

The IP-Port-Range Attribute MAY appear in an Accounting-Request packet.

The IP-Port-Range Attribute MUST NOT appear in any other RADIUS packet.

The format of the IP-Port-Range Attribute is shown in Figure 2.

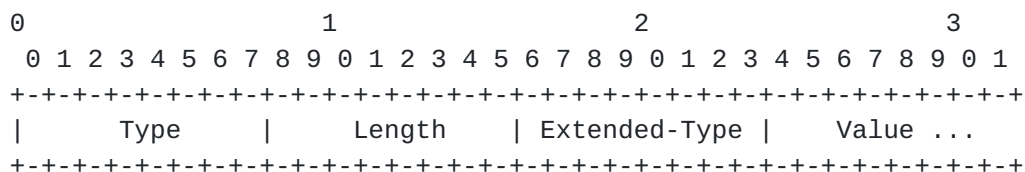


Figure 2

Type

241 (To be confirmed by IANA).

Length

This field indicates the total length in bytes of all fields of this attribute, including the Type, Length, Extended-Type, and the entire length of the embedded TLVs.

Extended-Type

TBD2.

Value

This field contains a set of TLVs as follows:

IP-Port-Type TLV

This TLV contains a value that indicates the IP port type.
Refer to [Section 3.2.1](#).

IP-Port-Alloc TLV

This TLV contains a flag to indicate that the range of the specified IP ports for either allocation or deallocation. This TLV MUST be included as part of the IP-Port-Range Attribute.
Refer to [Section 3.2.8](#).

IP-Port-Range-Start TLV

This TLV contains the smallest port number of a range of contiguous IP ports. To report the port allocation, this TLV MUST be included together with IP-Port-Range-End TLV as part of the IP-Port-Range Attribute. Refer to [Section 3.2.9](#).

IP-Port-Range-End TLV

This TLV contains the largest port number of a range of contiguous IP ports. To report the port allocation, this TLV MUST be included together with IP-Port-Range-Start TLV as part of the IP-Port-Range Attribute. Refer to [Section 3.2.10](#).

IP-Port-Ext-IPv4-Addr TLV

This TLV contains the IPv4 address that is associated with the IP port range, as collectively indicated in the IP-Port-Range-Start TLV and the IP-Port-Range-End TLV. This TLV is optionally included as part of the IP-Port-Range Attribute.
Refer to [Section 3.2.3](#).

IP-Port-Local-Id TLV

This TLV contains a local session identifier at the customer premise, such as MAC address, interface ID, VLAN ID, PPP sessions ID, VRF ID, IP address/prefix, etc. This TLV is optionally included as part of the IP-Port-Range Attribute.
Refer to [Section 3.2.11](#).

The IP-Port-Range attribute is associated with the following identifier: 241.Extended-Type(TBD2).

3.1.3. IP-Port-Forwarding-Map Attribute

This attribute is of type "TLV" as defined in the RADIUS Protocol Extensions [[RFC6929](#)]. It contains some sub-attributes and the requirement is as follows:

- o The IP-Port-Forwarding-Map Attribute MAY contain the IP-Port-Type TLV (see [Section 3.2.1](#)).
- o The IP-Port-Forwarding-Map Attribute MUST contain both IP-Port-Int-Port TLV (see [Section 3.2.6](#)) and the IP-Port-Ext-Port TLV (see [Section 3.2.7](#)).
- o If the internal realm is with IPv4 address family, the IP-Port-Forwarding-Map Attribute MUST contain the IP-Port-Int-IPv4-Addr TLV (see [Section 3.2.4](#)); if the internal realm is with IPv6 address family, the IP-Port-Forwarding-Map Attribute MUST contain the IP-Port-Int-IPv6-Addr TLV (see [Section 3.2.5](#)).
- o The IP-Port-Forwarding-Map Attribute MAY contain the IP-Port-Ext-IPv4-Addr TLV (see [Section 3.2.3](#)).
- o The IP-Port-Forwarding-Map Attribute MAY contain the IP-Port-Local-Id TLV (see [Section 3.2.11](#)).

The attribute contains a 2-byte IP internal port number and a 2-byte IP external port number. The internal port number is associated with an internal IPv4 or IPv6 address that MUST always be included. The external port number is associated with a specific external IPv4 address if included, but otherwise with all external IPv4 addresses for the end user.

If the IP-Port-Type TLV is included as part of the IP-Port-Forwarding-Map Attribute, the port mapping is associated with the specific IP transport protocol as specified in the IP-Port-Type TLV, but otherwise is for all IP transport protocols.

The IP-Port-Forwarding-Map Attribute MAY appear in an Access-Accept packet. It MAY also appear in an Access-Request packet to indicate a preferred port mapping by the device co-located with NAS. However the server is not required to honor such a preference.

The IP-Port-Forwarding-Map Attribute MAY appear in a CoA-Request packet.

The IP-Port-Forwarding-Map Attribute MAY also appear in an Accounting-Request packet.

The IP-Port-Forwarding-Map Attribute MUST NOT appear in any other RADIUS packet.

The format of the IP-Port-Forwarding-Map Attribute is shown in Figure 3.

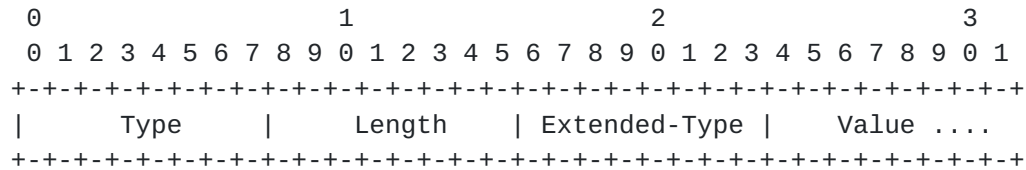


Figure 3

Type

241 (To be confirmed by IANA).

Length

This field indicates the total length in bytes of all fields of this attribute, including the Type, Length, Extended-Type, and the entire length of the embedded TLVs.

Extended-Type

TBD3.

Value

This field contains a set of TLVs as follows:

IP-Port-Type TLV

This TLV contains a value that indicates the IP port type. Refer to [Section 3.2.1](#).

IP-Port-Int-Port TLV

This TLV contains an internal IP port number associated with an internal IPv4 or IPv6 address. This TLV MUST be included together with IP-Port-Ext-Port TLV as part of the IP-Port-Forwarding-Map attribute. Refer to [Section 3.2.6](#).

IP-Port-Ext-Port TLV

This TLV contains an external IP port number associated with an external IPv4 address. This TLV MUST be included together with IP-Port-Int-Port TLV as part of the IP-Port-Forwarding-Map attribute. Refer to [Section 3.2.7](#).

IP-Port-Int-IPv4-Addr TLV

This TLV contains an IPv4 address that is associated with the internal IP port number contained in the IP-Port-Int-Port TLV. For internal realm with IPv4 address family, this TLV MUST be included as part of the IP-Port-Forwarding-Map Attribute. Refer to [Section 3.2.4](#).

IP-Port-Int-IPv6-Addr TLV

This TLV contains an IPv6 address that is associated with the internal IP port number contained in the IP-Port-Int-Port TLV. For internal realm with IPv6 address family, this TLV MUST be included as part of the IP-Port-Forwarding-Map Attribute. Refer to [Section 3.2.5](#).

IP-Port-Ext-IPv4-Addr TLV

This TLV contains an IPv4 address that is associated with the external IP port number contained in the IP-Port-Ext-Port TLV. This TLV MAY be included as part of the IP-Port-Forwarding-Map Attribute. Refer to [Section 3.2.3](#).

IP-Port-Local-Id TLV

This TLV contains a local session identifier at the customer premise, such as MAC address, interface ID, VLAN ID, PPP sessions ID, VRF ID, IP address/prefix, etc. This TLV is optionally included as part of the IP-Port-Forwarding-Map Attribute. Refer to [Section 3.2.11](#).

The IP-Port-Forwarding-Map Attribute is associated with the following identifier: 241.Extended-Type(TBD3).

[3.2.](#) RADIUS TLVs for IP Ports

The TLVs that are included in the three attributes (see [Section 3.1](#)) are defined in the following sub-sections. These TLVs use the format defined in [\[RFC6929\]](#). As the three attributes carry similar data, we have defined a common set of TLVs which are used for all three attributes. That is, the TLVs have the same name and number, when encapsulated in any one of the three parent attributes. See

When the IP-Port-Type TLV is included within a RADIUS Attribute, the associated attribute is applied to the IP transport protocol as indicated by the Protocol-Number only, such as TCP, UDP, SCTP [RFC4960], DCCP [RFC4340], etc.

3.2.2. IP-Port-Limit TLV

The format of IP-Port-Limit TLV is shown in Figure 5. This attribute carries IPFIX Information Element "sourceTransportPortsLimit (TBAX1), which indicates the maximum number of IP transport ports as a limit for an end user to use that is associated with one or more IPv4 or IPv6 addresses.

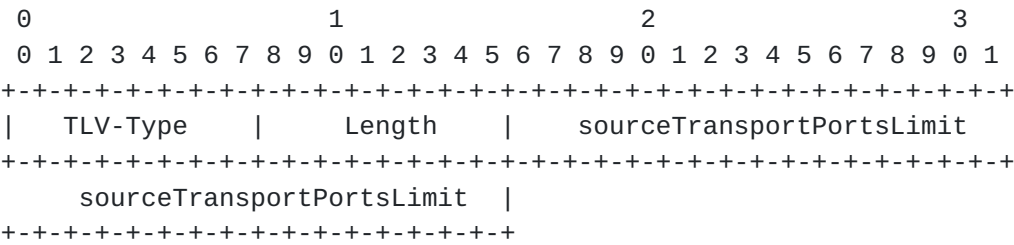


Figure 5

TLV-Type

2

Length

6

sourceTransportPortsLimit

Integer. This field contains the data (unsigned16) of sourceTransportPortsLimit (TBAX1) defined in IPFIX, right justified, and the unused bits in this field MUST be set to zero.

IP-Port-Limit TLV MUST be included as part of the IP-Port-Limit-Info Attribute (refer to [Section 3.1.1](#)), identified as 241.TBD1.2.

3.2.3. IP-Port-Ext-IPv4-Addr TLV

The format of IP-Port-Ext-IPv4-Addr TLV is shown in Figure 6. This attribute carries IPFIX Information Element 225, "postNATSourceIPv4Address", which is the IPv4 source address after NAT operation (refer to [[IPFIX](#)]).

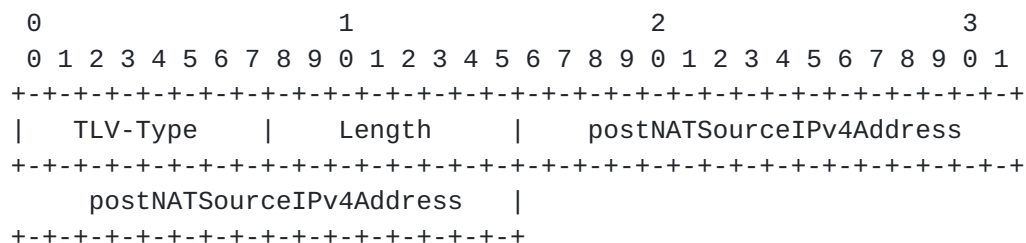


Figure 6

TLV-Type

3

Length

6

postNATSourceIPv4Address

Integer. This field contains the data (ipv4Address) of postNATSourceIPv4Address (225) defined in IPFIX.

IP-Port-Ext-IPv4-Addr TLV MAY be included in the following Attributes:

- o IP-Port-Limit-Info Attribute, identified as 241.TBD1.3 (see [Section 3.1.1](#)).
- o IP-Port-Range Attribute, identified as 241.TBD2.3 (see [Section 3.1.2](#)).
- o IP-Port-Forwarding-Mapping Attribute, identified as 241.TBD3.3 (see [Section 3.1.3](#)).

[3.2.4](#). IP-Port-Int-IPv4-Addr TLV

The format of IP-Port-Int-IPv4 TLV is shown in Figure 7. This attribute carries IPFIX Information Element 8, "sourceIPv4Address", which is the IPv4 source address before NAT operation (refer to [\[IPFIX\]](#)).

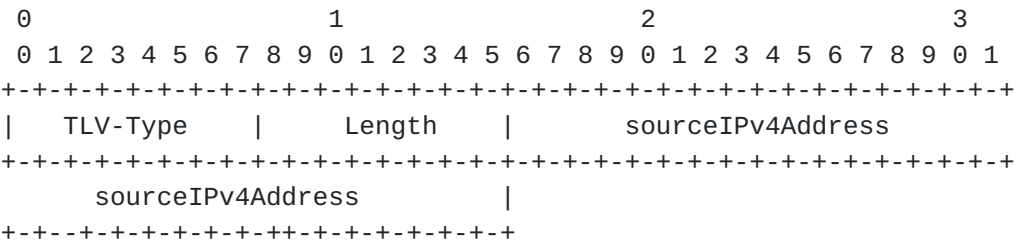


Figure 7

TLV-Type

4

Length

6

sourceIPv4Address

Integer. This field contains the data (ipv4Address) of sourceIPv4Address (8) defined in IPFIX.

If the internal realm is with IPv4 address family, the IP-Port-Int-IPv4-Addr TLV MUST be included as part of the IP-Port-Forwarding-Map Attribute (refer to [Section 3.1.3](#)), identified as 241.TBD3.4.

3.2.5. IP-Port-Int-IPv6-Addr TLV

The format of IP-Port-Int-IPv6-Addr TLV is shown in Figure 8. This attribute carries IPFIX Information Element 27, "sourceIPv6Address", which is the IPv6 source address before NAT operation (refer to [\[IPFIX\]](#)).

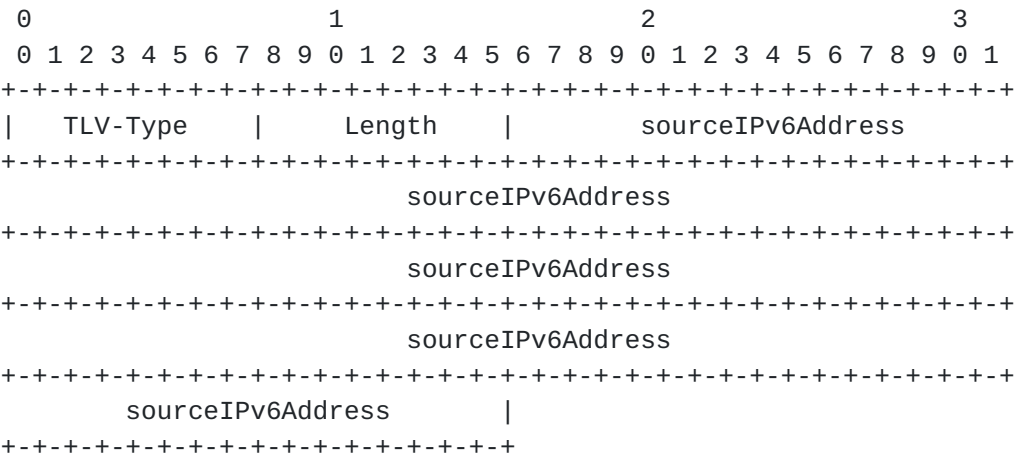


Figure 8

TLV-Type

5

Length

18

sourceIPv6Address

IPv6 address (128 bits). This field contains the data (ipV6Address) of sourceIPv6Address (27) defined in IPFIX.

If the internal realm is with IPv6 address family, the IP-Port-Int-IPv6-Addr TLV MUST be included as part of the IP-Port-Forwarding-Map Attribute (refer to [Section 3.1.3](#)), identified as 241.TBD3.5.

3.2.6. IP-Port-Int-Port TLV

The format of IP-Port-Int-Port TLV is shown in Figure 9. This attribute carries IPFIX Information Element 7, "sourceTransportPort", which is the source transport number associated with an internal IPv4 or IPv6 address (refer to [\[IPFIX\]](#)). The attribute is encoded in 32 bits as per the recommendation in [Appendix A.2.1 of \[RFC6158\]](#).

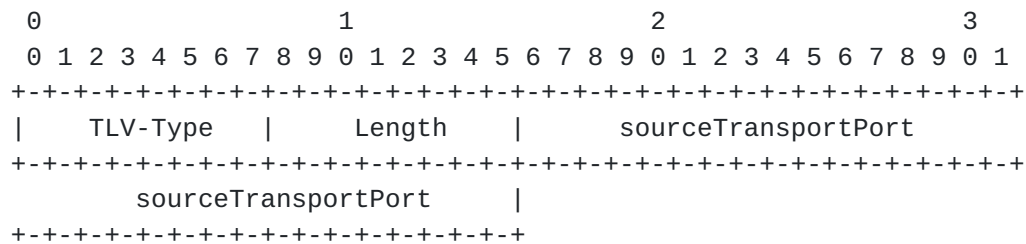


Figure 9

TLV-Type

6

Length

6

sourceTransportPort

Integer. This field contains the data (unsigned16) of sourceTrasnportPort (7) defined in IPFIX, right justified, and unused bits MUST be set to zero.

IP-Port-Int-Port TLV MUST be included as part of the IP-Port-Forwarding-Map Attribute (refer to [Section 3.1.3](#)), identified as 241.TBD3.6.

3.2.7. IP-Port-Ext-Port TLV

The format of IP-Port-Ext-Port TLV is shown in Figure 10. This attribute carries IPFIX Information Element 227, "postNAPTSourceTransportPort", which is the transport number associated with an external IPv4 address(refer to [\[IPFIX\]](#)). The attribute is encoded in 32 bits as per the recommendation in [Appendix A.2.1 of \[RFC6158\]](#).

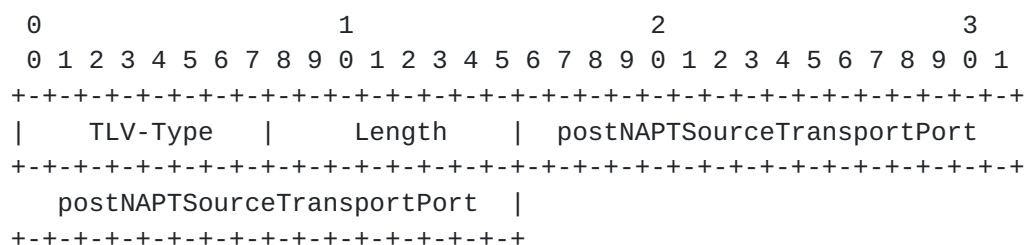


Figure 10

TLV-Type

7

Length

6

postNAPTSourceTransportPort

Integer. This field contains the data (unsigned16) of postNAPTSourceTrasnportPort (227) defined in IPFIX, right justified, and unused bits MUST be set to zero.

IP-Port-Ext-Port TLV MUST be included as part of the IP-Port-Forwarding-Map Attribute (refer to [Section 3.1.3](#)), identified as 241.TBD3.7.

3.2.8. IP-Port-Alloc TLV

The format of IP-Port-Alloc TLV is shown in Figure 11. This attribute carries IPFIX Information Element 230, "natEvent", which is a flag to indicate an action of NAT operation (refer to [[IPFIX](#)]).

When the value of natEvent is "1" (Create event), it means to allocate a range of transport ports; when the value is "2", it means to deallocate a range of transports ports. For the purpose of this TLV, no other value is used.

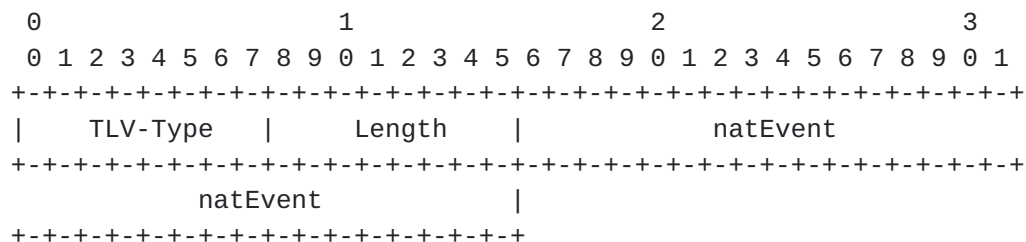


Figure 11

TLV-Type

8

Length

6

natEvent

Integer. This field contains the data (unsigned8) of natEvent (230) defined in IPFIX, right justified, and unused bits MUST be set to zero. It indicates the allocation or deallocation of a range of IP ports as follows:

1:

Allocation

2:

Deallocation

Reserved:

0.

IP-Port-Alloc TLV MUST be included as part of the IP-Port-Range Attribute (refer to [Section 3.1.2](#)), identified as 241.TBD2.8.

[3.2.9](#). IP-Port-Range-Start TLV

The format of IP-Port-Range-Start TLV is shown in Figure 12. This attribute carries IPFIX Information Element 361, "portRangeStart", which is the smallest port number of a range of contiguous transport ports (refer to [[IPFIX](#)]). The attribute is encoded in 32 bits as per the recommendation in [Appendix A.2.1 of \[RFC6158\]](#).

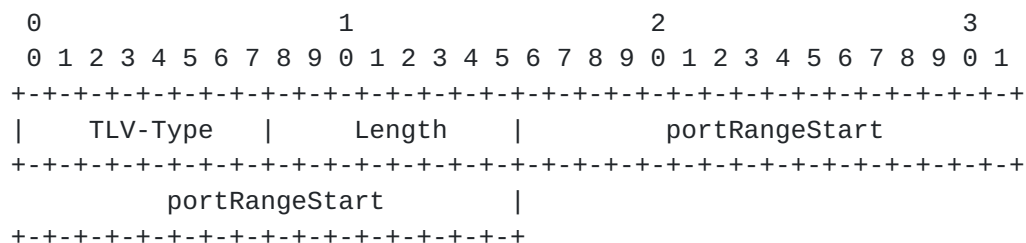


Figure 12

TLV-Type

9

Length

6

portRangeStart

Integer. This field contains the data (unsigned16) of (361) defined in IPFIX, right justified, and unused bits MUST be set to zero.

IP-Port-Range-Start TLV is included as part of the IP-Port-Range Attribute (refer to [Section 3.1.2](#)), identified as 241.TBD2.9.

3.2.10. IP-Port-Range-End TLV

The format of IP-Port-Range-End TLV is shown in Figure 13. This attribute carries IPFIX Information Element 362, "portRangeEnd", which is the largest port number of a range of contiguous transport ports (refer to [[IPFIX](#)]). The attribute is encoded in 32 bits as per the recommendation in [Appendix A.2.1 of \[RFC6158\]](#).

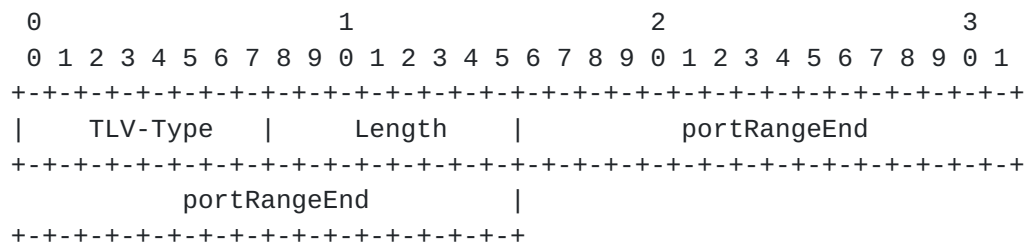


Figure 13

TLV-Type

10

Length

6

portRangeEnd

Integer. This field contains the data (unsigned16) of (362) defined in IPFIX, right justified, and unused bits MUST be set to zero.

IP-Port-Range-End TLV is included as part of the IP-Port-Range Attribute (refer to [Section 3.1.2](#)), identified as 241.TBD2.10.

- o IP-Port-Range Attribute, identified as 241.TBD2.11 (see [Section 3.1.2](#)).
- o IP-Port-Forwarding-Mapping Attribute, identified as 241.TBD3.11 (see [Section 3.1.3](#)).

4. Applications, Use Cases and Examples

This section describes some applications and use cases to illustrate the use of the attributes proposed in this document.

4.1. Managing CGN Port Behavior using RADIUS

In a broadband network, customer information is usually stored on a RADIUS server, and the BNG acts as a NAS. The communication between the NAS and the RADIUS server is triggered by a user when it signs in to the Internet service, where either PPP or DHCP/DHCPv6 is used. When a user signs in, the NAS sends a RADIUS Access-Request message to the RADIUS server. The RADIUS server validates the request, and if the validation succeeds, it in turn sends back a RADIUS Access-Accept message. The Access-Accept message carries configuration information specific to that user, back to the NAS, where some of the information would pass on to the requesting user via PPP or DHCP/DHCPv6.

A CGN function in a broadband network is most likely be co-located on a BNG. In that case, parameters for CGN port mapping behavior for users can be configured on the RADIUS server. When a user signs in to the Internet service, the associated parameters can be conveyed to the NAS, and proper configuration is accomplished on the CGN device for that user.

Also, CGN operation status such as CGN port allocation and deallocation for a specific user on the BNG can also be transmitted back to the RADIUS server for accounting purpose using the RADIUS protocol.

RADIUS protocol has already been widely deployed in broadband networks to manage BNG, thus the functionality described in this specification introduces little overhead to the existing network operation.

In the following sub-sections, we describe how to manage CGN behavior using RADIUS protocol, with required RADIUS extensions proposed in [Section 3](#).

4.1.1.1. Configure IP Port Limit for a User

In the face of IPv4 address shortage, there are currently proposals to multiplex multiple users' connections over a number of shared IPv4 addresses, such as Carrier Grade NAT [[RFC6888](#)], Dual-Stack Lite [[RFC6333](#)], NAT64 [[RFC6146](#)], etc. As a result, a single IPv4 public address may be shared by hundreds or even thousands of users. As indicated in [[RFC6269](#)], it is therefore necessary to impose limits on the total number of ports available to an individual user to ensure that the shared resource, i.e., the IPv4 address, remains available in some capacity to all the users using it. The support of IP port limit is also documented in [[RFC6888](#)] as a requirement for CGN.

The IP port limit imposed to an end user may be on the total number of IP source transport ports, or a specific IP transport protocol as defined in [Section 3.1.1](#).

The per-user based IP port limit is configured on a RADIUS server, along with other user information such as credentials.

When a user signs in to the Internet service successfully, the IP port limit for the subscriber is passed by the RADIUS server to the BNG, acting as a NAS and co-located with the CGN, using the IP-Port-Limit-Info RADIUS attribute (defined in [Section 3.1.1](#)), along with other configuration parameters. While some parameters are passed to the user, the IP port limit is recorded on the CGN device for imposing the usage of IP transport ports for that user.

Figure 15 illustrates how RADIUS protocol is used to configure the maximum number of TCP/UDP ports for a given user on a CGN device.

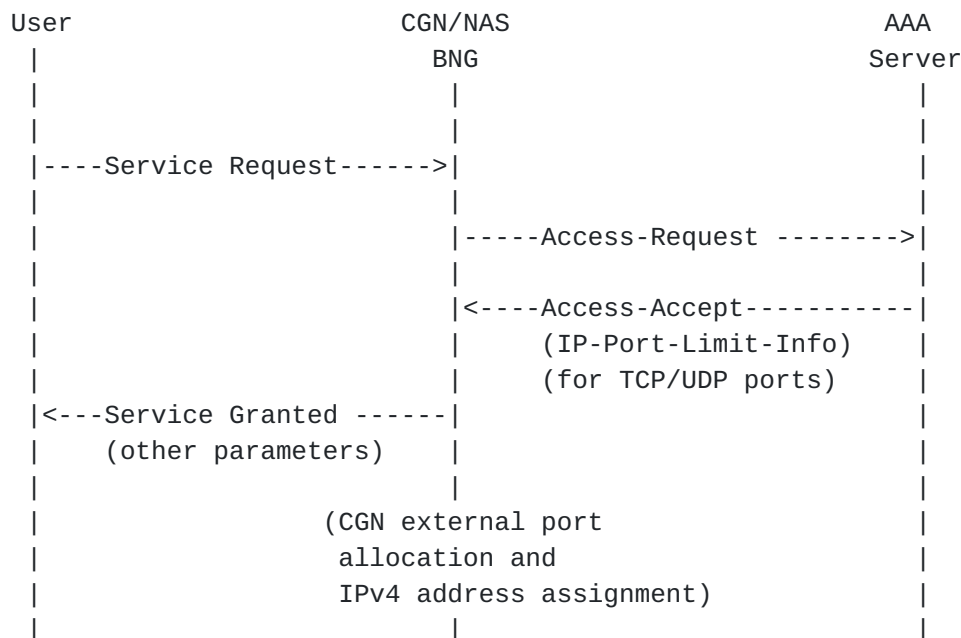


Figure 15: RADIUS Message Flow for Configuring CGN Port Limit

The IP port limit created on a CGN device for a specific user using RADIUS extension may be changed using RADIUS CoA message [[RFC5176](#)] that carries the same RADIUS attribute. The CoA message may be sent from the RADIUS server directly to the NAS, which once accepts and sends back a RADIUS CoA ACK message, the new IP port limit replaces the previous one.

Figure 16 illustrates how RADIUS protocol is used to increase the TCP/UDP port limit from 1024 to 2048 on a CGN device for a specific user.

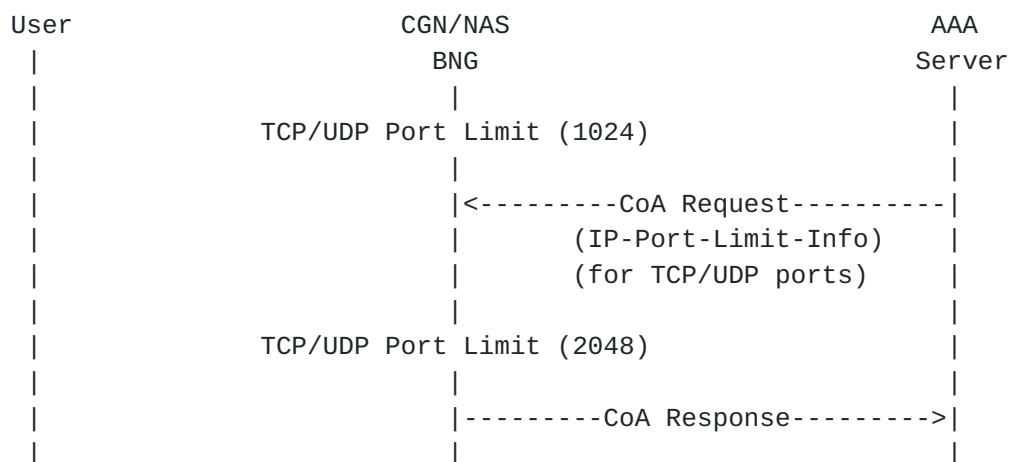


Figure 16: RADIUS Message Flow for changing a user's CGN port limit

4.1.2. Report IP Port Allocation/Deallocation

Upon obtaining the IP port limit for a user, the CGN device needs to allocate an IP transport port for the user when receiving a new IP flow sent from that user.

As one practice, a CGN may allocate a block of IP ports for a specific user, instead of one port at a time, and within each port block, the ports may be randomly distributed or in consecutive fashion. When a CGN device allocates a block of transport ports, the information can be easily conveyed to the RADIUS server by a new RADIUS attribute called the IP-Port-Range (defined in [Section 3.1.2](#)). The CGN device may allocate one or more IP port ranges, where each range contains a set of numbers representing IP transport ports, and the total number of ports MUST be less or equal to the associated IP port limit imposed for that user. A CGN device may choose to allocate a small port range, and allocate more at a later time as needed; such practice is good because its randomization in nature.

At the same time, the CGN device also needs to decide the shared IPv4 address for that user. The shared IPv4 address and the pre-allocated IP port range are both passed to the RADIUS server.

When a user initiates an IP flow, the CGN device randomly selects a transport port number from the associated and pre-allocated IP port range for that user to replace the original source port number, along with the replacement of the source IP address by the shared IPv4 address.

A CGN device may decide to "free" a previously assigned set of IP ports that have been allocated for a specific user but not currently in use, and with that, the CGN device must send the information of the deallocated IP port range along with the shared IPv4 address to the RADIUS server.

Figure 17 illustrates how RADIUS protocol is used to report a set of ports allocated and deallocated, respectively, by a NAT64 device for a specific user to the RADIUS server.

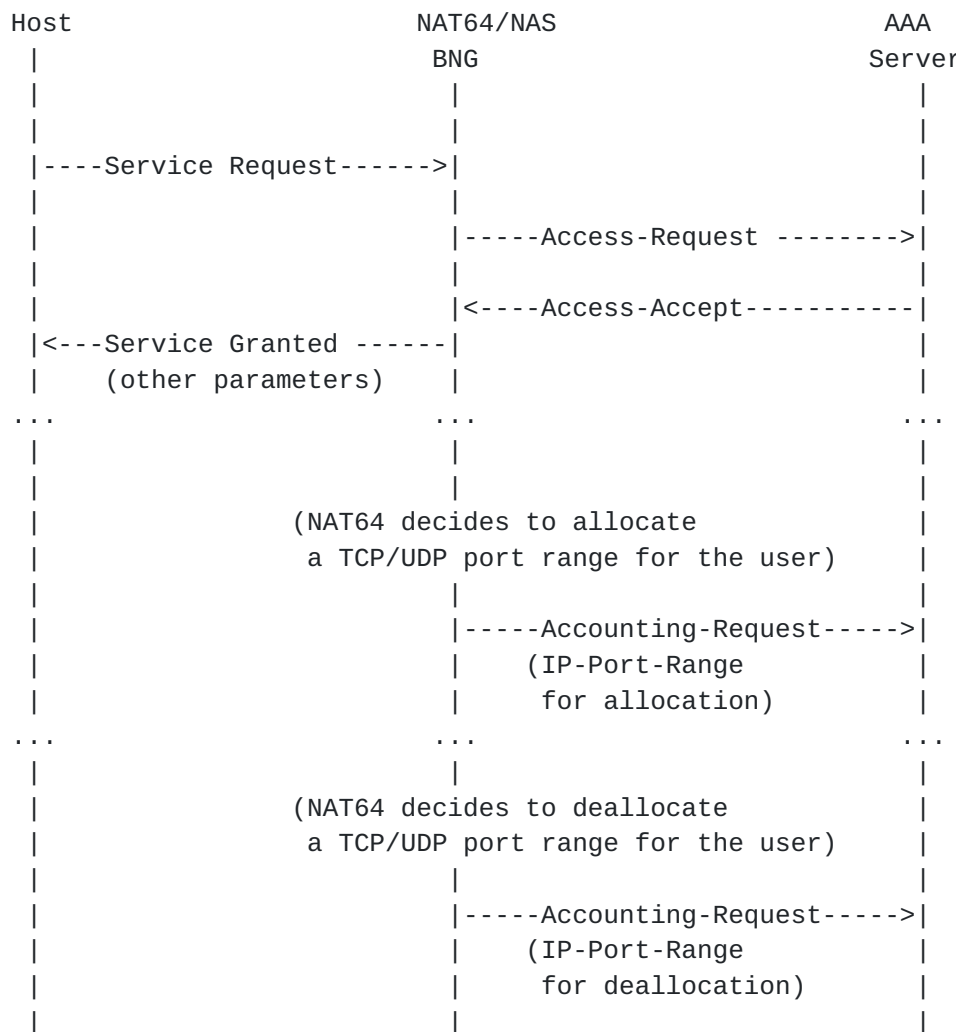


Figure 17: RADIUS Message Flow for reporting NAT64 allocation/deallocation of a port set

4.1.3. Configure Forwarding Port Mapping

In most scenarios, the port mapping on a NAT device is dynamically created when the IP packets of an IP connection initiated by a user arrives. For some applications, the port mapping needs to be pre-defined allowing IP packets of applications from outside a CGN device to pass through and "port forwarded" to the correct user located behind the CGN device.

Port Control Protocol [[RFC6887](#)], provides a mechanism to create a mapping from an external IP address and port to an internal IP address and port on a CGN device just to achieve the "port forwarding" purpose. PCP is a server-client protocol capable of creating or deleting a mapping along with a rich set of features on a CGN device in dynamic fashion. In some deployment, all users need is

a few, typically just one pre-configured port mapping for applications such as web cam at home, and the lifetime of such a port mapping remains valid throughout the duration of the customer's Internet service connection time. In such an environment, it is possible to statically configure a port mapping on the RADIUS server for a user and let the RADIUS protocol to propagate the information to the associated CGN device.

Note that this document targets deployments where a AAA server is responsible de instructing NAT mappings for a given subscriber and does not make any assumption about the host's capabilities with regards to port forwarding control. This deployment is complementary to PCP given that PCP targets a different deployment model where an application (on the host) controls its mappings in an upstream CPE, CGN, firewall, etc.

Figure 18 illustrates how RADIUS protocol is used to configure a forwarding port mapping on a NAT44 device by using RADIUS protocol.

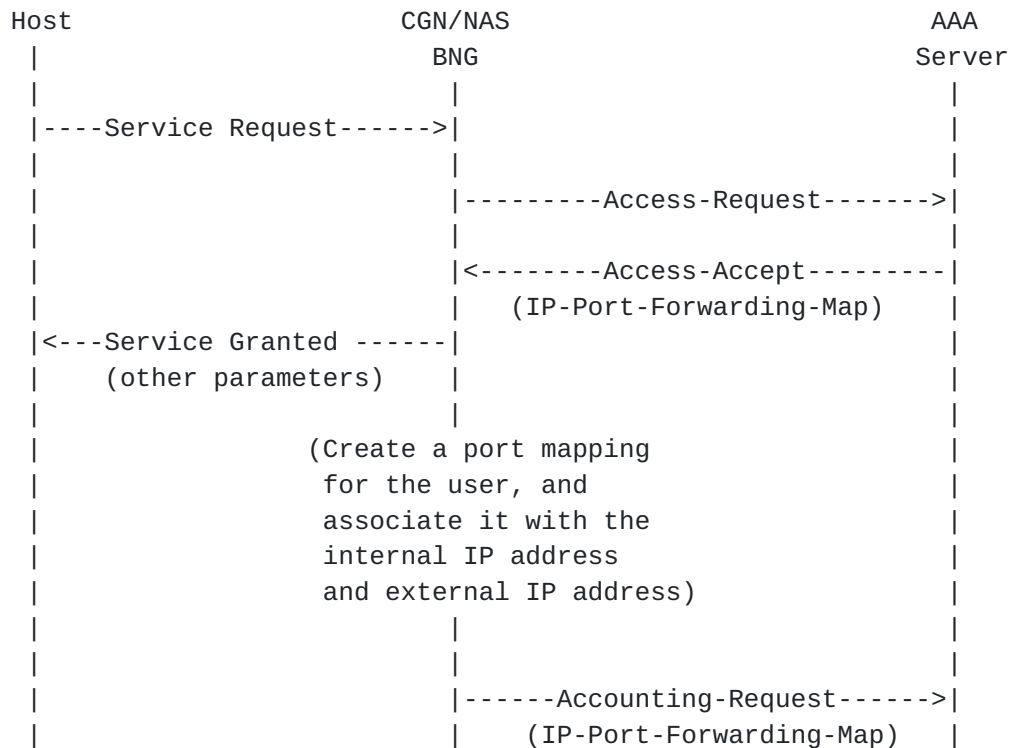


Figure 18: RADIUS Message Flow for configuring a forwarding port mapping

A port forwarding mapping that is created on a CGN device using RADIUS extension as described above may also be changed using RADIUS CoA message [[RFC5176](#)] that carries the same RADIUS association. The CoA message may be sent from the RADIUS server directly to the NAS,

which once accepts and sends back a RADIUS CoA ACK message, the new port forwarding mapping then replaces the previous one.

Figure 19 illustrates how RADIUS protocol is used to change an existing port mapping from (a:X) to (a:Y), where "a" is an internal port, and "X" and "Y" are external ports, respectively, for a specific user with a specific IP address

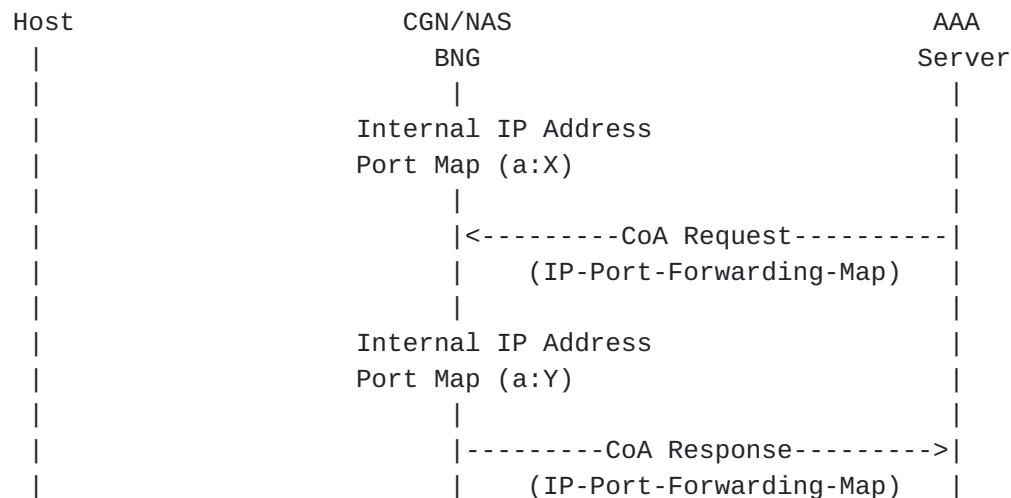


Figure 19: RADIUS Message Flow for changing a user's forwarding port mapping

4.1.4. An Example

An Internet Service Provider (ISP) assigns TCP/UDP 500 ports for the user Joe. This number is the limit that can be used for TCP/UDP ports on a CGN device for Joe, and is configured on a RADIUS server. Also, Joe asks for a pre-defined port forwarding mapping on the CGN device for his web cam applications (external port 5000 maps to internal port 1234).

When Joe successfully connects to the Internet service, the RADIUS server conveys the TCP/UDP port limit (500) and the forwarding port mapping (external port 5000 to internal port 1234) to the CGN device, using IP-Port-Limit-Info Attribute and IP-Port-Forwarding-Map attribute, respectively, carried by an Access-Accept message to the BNG where NAS and CGN co-located.

Upon receiving the first outbound IP packet sent from Joe's laptop, the CGN device decides to allocate a small port pool that contains 40 consecutive ports, from 3500 to 3540, inclusively, and also assign a shared IPv4 address 192.0.2.15, for Joe. The CGN device also randomly selects one port from the allocated range (say 3519) and use that port to replace the original source port in outbound IP packets.

For accounting purpose, the CGN device passes this port range (3500-3540) and the shared IPv4 address 192.0.2.15 together to the RADIUS server using IP-Port-Range attribute carried by an Accounting-Request message.

When Joe works on more applications with more outbound IP mappings and the port pool (3500-3540) is close to exhaust, the CGN device allocates a second port pool (8500-8800) in a similar fashion, and also passes the new port range (8500-8800) and IPv4 address 192.0.2.15 together to the RADIUS server using IP-Port-Range attribute carried by an Accounting-Request message. Note when the CGN allocates more ports, it needs to assure that the total number of ports allocated for Joe is within the limit.

Joe decides to upgrade his service agreement with more TCP/UDP ports allowed (up to 1000 ports). The ISP updates the information in Joe's profile on the RADIUS server, which then sends a CoA-Request message that carries the IP-Port-Limit-Info Attribute with 1000 ports to the CGN device; the CGN device in turn sends back a CoA-ACK message. With that, Joe enjoys more available TCP/UDP ports for his applications.

When Joe is not using his service, most of the IP mappings are closed with their associated TCP/UDP ports released on the CGN device, which then sends the relevant information back to the RADIUS server using IP-Port-Range attribute carried by Accounting-Request message.

Throughout Joe's connection with his ISP Internet service, applications can communicate with his web cam at home from external realm directly traversing the pre-configured mapping on the CGN device.

When Joe disconnects from his Internet service, the CGN device will deallocate all TCP/UDP ports as well as the port-forwarding mapping, and send the relevant information to the RADIUS server.

4.2. Report Assigned Port Set for a Visiting UE

Figure 20 illustrates an example of the flow exchange which occurs when a visiting User Equipment (UE) connects to a CPE offering WLAN service.

For identification purposes (see [[RFC6967](#)]), once the CPE assigns a port set, it issues a RADIUS message to report the assigned port set.

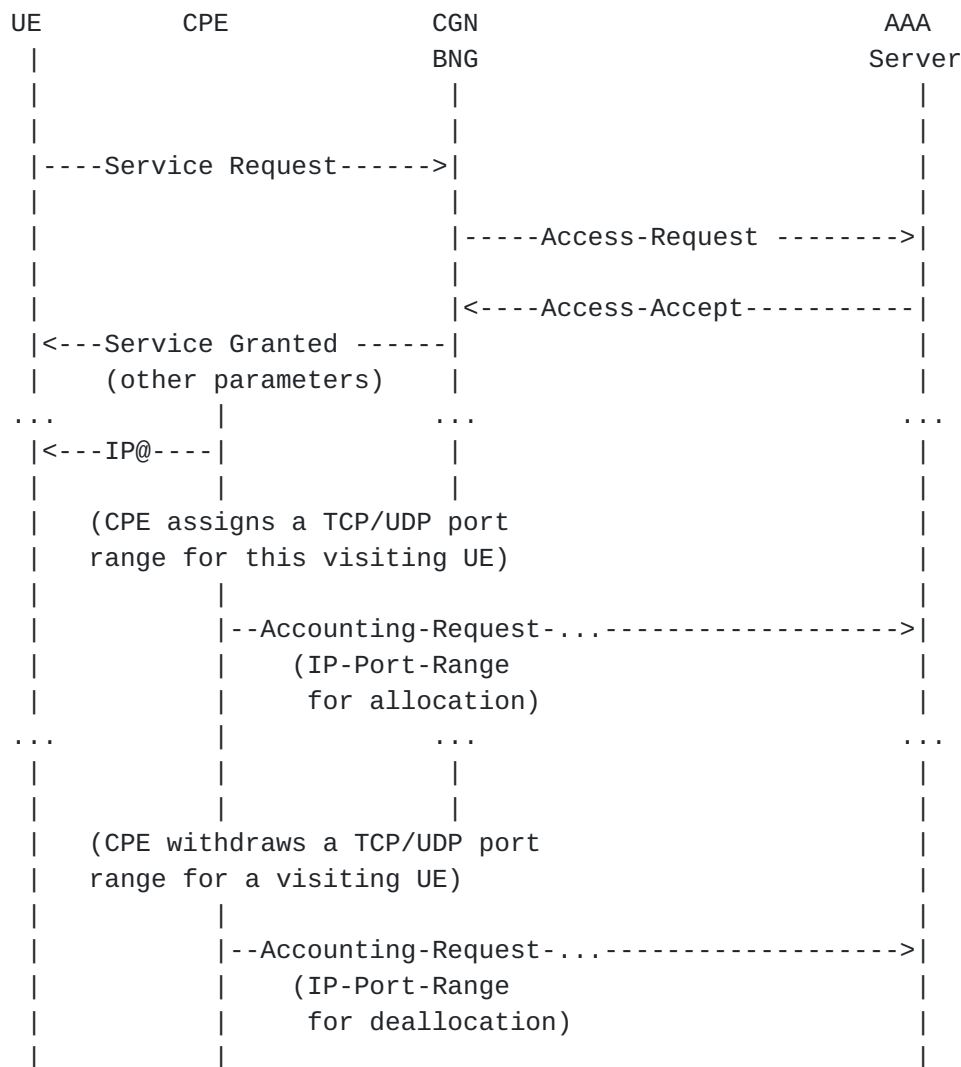


Figure 20: RADIUS Message Flow for reporting CPE allocation/deallocation of a port set to a visiting UE

5. Table of Attributes

This document proposes three new RADIUS attributes and their formats are as follows:

- o IP-Port-Limit-Info: 241.TBD1.
- o IP-Port-Range: 241.TBD2.
- o IP-Port-Forwarding-Map: 241.TBD3.

Note to IANA: it is assumed that Extended-Type-1 "241" will be used for these attributes.

The following table provides a guide as what type of RADIUS packets that may contain these attributes, and in what quantity.

Request	Accept	Reject	Challenge	Acct. Request	#	Attribute
0+	0+	0	0	0+	TBA	IP-Port-Limit-Info
0	0	0	0	0+	TBA	IP-Port-Range
0+	0+	0	0	0+	TBA	IP-Port-Forwarding-Map

The following table defines the meaning of the above table entries.

0 This attribute MUST NOT be present in packet.

0+ Zero or more instances of this attribute MAY be present in packet.

6. Security Considerations

This document does not introduce any security issue other than the ones already identified in RADIUS [[RFC2865](#)] and [[RFC5176](#)] for CoA messages. Known RADIUS vulnerabilities apply to this specification. For example, if RADIUS packets are sent in the clear, an attacker in the communication path between the RADIUS client and server may glean information that it will use to prevent a legitimate user to access the service by appropriately setting the maximum number of IP ports conveyed in an IP-Port-Limit-Info Attribute, exhaust the port quota of a user by installing many mapping entries (IP-Port-Forwarding-Map Attribute), prevent incoming traffic to be delivered to its legitimate destination by manipulating the mapping entries installed by means of an IP-Port-Forwarding-Map Attribute, discover the IP address and port range assigned to a given user and which is reported in an IP-Port-Range Attribute, etc. The root cause of these attack vectors is the communication between the RADIUS client and server.

The IP-Port-Local-Id TLV includes an identifier of which the type and length is deployment and implementation dependent. This identifier might carry privacy sensitive information. It is therefore RECOMMENDED to utilize identifiers that do not have such privacy concerns.

This document targets deployments where a trusted relationship is in place between the RADIUS client and server with communication optionally secured by IPsec or Transport Layer Security (TLS) [[RFC6614](#)].

7. IANA Considerations

This document requires new code point assignments for both IPFIX Information Elements and RADIUS attributes as explained in the following sub-sections.

It is assumed that Extended-Type-1 "241" will be used for RADIUS attributes in [Section 7.2](#).

7.1. IANA Considerations on New IPFIX Information Elements

The following is a new IPFIX Information Element as requested by this document (refer to [Section 3.2.2](#)) :

o sourceTransportPortsLimit:

- * Name: sourceTransportPortsLimit.
- * Element ID: TBAX1.
- * Description: This Information Element contains the maximum number of IP source transport ports that can be used by an end user when sending IP packets; each user is associated with one or more (source) IPv4 or IPv6 addresses. This IE is particularly useful in address sharing deployments that adhere to REQ-4 of [[RFC6888](#)]. Limiting the number of ports assigned to each user ensures fairness among users and mitigates the denial-of-service attack that a user could launch against other users through the address sharing device in order to grab more ports.
- * Data type: unsigned16.
- * Data type semantics: totalCounter.
- * Data type unit: ports.
- * Data value range: from 1 to 65535.

7.2. IANA Considerations on New RADIUS Attributes

The authors request that Attribute Types and Attribute Values defined in this document be registered by the Internet Assigned Numbers Authority (IANA) from the RADIUS namespaces as described in the "IANA Considerations" section of [[RFC3575](#)], in accordance with [BCP 26](#) [[RFC5226](#)]. For RADIUS packets, attributes and registries created by this document IANA is requested to place them at <http://www.iana.org/assignments/radius-types>.

In particular, this document defines three new RADIUS attributes, entitled "IP-Port-Limit-Info" (see [Section 3.1.1](#)), "IP-Port-Range" (see [Section 3.1.2](#)) and "IP-Port-Forwarding-Map" (see [Section 3.1.3](#)), with assigned values of 241.TBD1, 241.TBD2 and 241.TBD3 from the Short Extended Space of [[RFC6929](#)]:

Type	Name	Meaning
----	----	-----
241.TBD1	IP-Port-Limit-Info	see Section 3.1.1
241.TBD2	IP-Port-Range	see Section 3.1.2
241.TBD3	IP-Port-Forwarding-Map	see Section 3.1.3

7.3. IANA Considerations on New RADIUS TLVs

This specification requests allocation of the following TLVs:

Name	Value	Meaning
----	-----	-----
IP-Port-Type	1	see Section 3.2.1
IP-Port-Limit	2	see Section 3.2.2
IP-Port-Ext-IPv4-Addr	3	see Section 3.2.3
IP-Port-Int-IPv4-Addr	4	see Section 3.2.4
IP-Port-Int-IPv6-Addr	5	see Section 3.2.5
IP-Port-Int-Port	6	see Section 3.2.6
IP-Port-Ext-Port	7	see Section 3.2.7
IP-Port-Alloc	8	see Section 3.2.8
IP-Port-Range-Start	9	see Section 3.2.9
IP-Port-Range-End	10	see Section 3.2.10
IP-Port-Local-Id	11	see Section 3.2.11

8. Acknowledgements

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