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**Remote Authentication Dial In User Service (RADIUS) Protocol
Extensions
draft-ietf-radext-radius-extensions-06.txt**

Abstract

The Remote Authentication Dial In User Service (RADIUS) protocol is nearing exhaustion of its current 8-bit Attribute Type space. In addition, experience shows a growing need for complex grouping, along with attributes which can carry more than 253 octets of data. This document defines changes to RADIUS which address all of the above problems.

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1. Introduction

Under current allocation pressure, we expect that the RADIUS Attribute Type space will be exhausted by 2014 or 2015. We therefore need a way to extend the type space, so that new specifications may continue to be developed. Other issues have also been shown with RADIUS. The attribute grouping method defined in [RFC2868] has been shown to be impractical, and a more powerful mechanism is needed. Multiple attributes have been defined which transport more than the 253 octets of data originally envisioned with the protocol. Each of these attributes is handled as a "special case" inside of RADIUS implementations, instead of as a general method. We therefore also need a standardized method of transporting large quantities of data. Finally, some vendors are close to allocating all of the Attributes within their Vendor-Specific Attribute space. It would be useful to leverage changes to the base protocol for extending the Vendor-Specific Attribute space.

We satisfy all of these requirements through the following modifications to RADIUS:

- * defining an "Extended Type" format, which adds 8 bits of "Extended Type" to the RADIUS Attribute Type space, by using one octet of the "Value" field. This method gives us a general way of extending the Attribute Type Space.
- * allocating 4 attributes as using the format of "Extended Type". This allocation extends the RADIUS Attribute Type Space by approximately 1000 values.
- * defining a "Long Extended Type" format, which inserts an additional octet between the "Extended Type" octet, and the "Value" field. This method gives us a general way of adding additional functionality to the protocol.
- * defining a method which uses the additional octet to indicate data fragmentation across multiple Attributes. This method provides a standard way for an Attribute to carry more than 253 octets of data.
- * allocating 2 attributes as using the format "Long Extended Type". This allocation extends the RADIUS Attribute Type Space by an additional 500 values.
- * defining a new "Type Length Value" (TLV) data type. The data type allows an attribute to carry TLVs as "sub-attributes", which can in turn encapsulate other TLVs as "sub-sub-attributes." This change creates a standard way to group a set of Attributes.

- * defining a new "extended Vendor-Specific" (EVS) data type. The data type allows an attribute to carry Vendor-Specific Attributes (VSAs) inside of the new attribute formats.
- * defining a new "integer64" data type. The data type allows counters which track more than 2^{32} octets of data.
- * allocating 6 attributes using the new EVS data type. This allocation extends the Vendor-Specific Attribute Type space by over 1500 values.
- * Define the "Vendor-ID" for Vendor-Specific attributes to encompass the entire 4 octets of the Vendor field. [\[RFC2865\]](#) [Section 5.26](#) defined it to be 3 octets, with the high octet being zero.

As with any protocol change, the changes defined here are the result of a series of compromises. We have tried to find a balance between flexibility, space in the RADIUS message, compatibility with existing deployments, and implementation difficulty.

[1.1.](#) Unmet Requirements

One requirement which was not met by the above modifications is to have an incentive for standards to use the new space. We would ideally like to deprecate the "Unassigned" attributes in the standard space, which would permit allocation, but under more stringent guidelines. However, [\[RFC5226\]](#) has no provisions for a "Deprecated" entry in an IANA managed registry.

It is RECOMMENDED that implementations support this specification. It is RECOMMENDED that new specifications use the formats defined in this specification.

The alternative to the above recommendations is a circular argument of not implementing this specification because no other standards reference it, and also not defining new standards referencing this specification because no implementations exist.

[1.2.](#) Terminology

This document uses the following terms:

silently discard

This means the implementation discards the packet without further processing. The implementation MAY provide the capability of logging the error, including the contents of the silently discarded packet, and SHOULD record the event in a statistics counter.

invalid attribute

This means that the Length field of an Attribute is valid (as per [\[RFC2865\]](#), [Section 5](#), top of page 25). However, the Value field of the attribute does not follow the format required by the data type defined for that Attribute. e.g. an Attribute of type "address" which encapsulates more than four, or less than four, octets of data. See [Section 2.7](#) for a more complete definition.

Standard space

Codes in the RADIUS Attribute Type Space that are allocated by IANA and that follow the format defined in [Section 5 of RFC 2865](#) [[RFC2865](#)].

Extended space

Codes in the RADIUS Attribute Type Space that require the extensions defined in this document, and are an extension of the standard space, but which cannot be represented within the standard space.

Short extended space

Codes in the extended space which use the "Extended Type" format.

Long extended space

Codes in the extended space which use the "Long Extended Type" format.

The following terms are used here with the meanings defined in [BCP 26](#) [[RFC5226](#)]: "name space", "assigned value", "registration", "Private Use", "Reserved", "Unassigned", "IETF Review", and "Standards Action".

[1.3.](#) Requirements Language

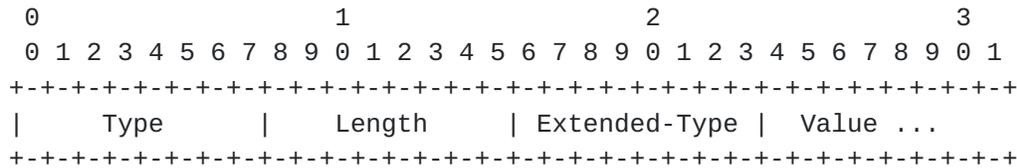
In this document, several words are used to signify the requirements of the specification. The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [\[RFC2119\]](#).

2. Extensions to RADIUS

This section defines two new attribute formats; "Extended Type"; and "Long Extended Type". It defines a new Type-Length-Value (TLV) data type, an Extended-Vendor-Specific (EVS) data type, and an Integer64 data type. It defines a new method for naming attributes and identifying Attributes using the new attribute formats. It finally defines the new term "invalid attribute", and describes how it affects implementations.

2.1. Extended Type

This section defines a new attribute format, called "Extended Type". A summary of the Attribute format is shown below. The fields are transmitted from left to right.



Type

This field is identical to the Type field of the Attribute format defined in [RFC2865] Section 5.

Length

This field is identical to the Length field of the Attribute format defined in [RFC2865] Section 5. Permitted values are between 4 and 255. If a client or server receives an Extended Attribute with a Length of 2 or 3, then that Attribute MUST be considered to be an "invalid attribute", and handled as per Section 2.7, below.

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified according to the policies and rules described in Section 10. Unlike the Type field defined in [RFC2865] Section 5, no values are allocated for experimental or implementation-specific use. Values 241-255 are reserved and SHOULD NOT be used.

The Extended-Type is meaningful only within a context defined by the Type field. That is, this field may be thought of as defining a new type space of the form "Type.Extended-Type". See Section 2.5, below, for additional discussion.

A RADIUS server MAY ignore Attributes with an unknown "Type.Extended-Type".

A RADIUS client MAY ignore Attributes with an unknown "Type.Extended-Type".

Value

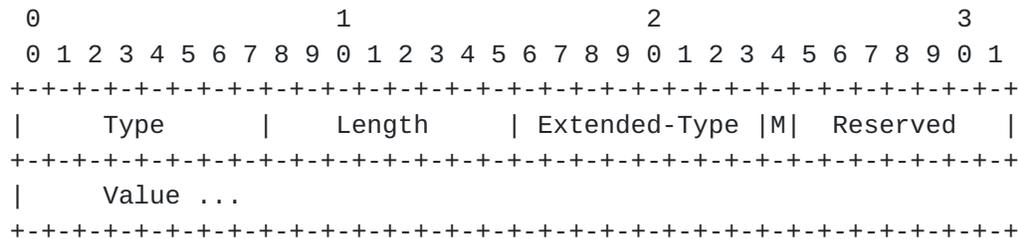
This field is similar to the Value field of the Attribute format defined in [RFC2865] Section 5. The format of the data SHOULD be a valid RADIUS data type.

The addition of the Extended-Type field decreases the maximum length for attributes of type "text" or "string" from 253 to 252 octets. Where an Attribute needs to carry more than 252 octets of data, the "Long Extended Type" format SHOULD be used.

Experience has shown that the "experimental" and "implementation specific" attributes defined in [RFC2865] Section 5 have had little practical value. We therefore do not continue that practice here with the Extended-Type field.

2.2. Long Extended Type

This section defines a new attribute format, called "Long Extended Type". It leverages the "Extended Type" format in order to permit the transport of attributes encapsulating more than 253 octets of data. A summary of the Attribute format is shown below. The fields are transmitted from left to right.



Type

This field is identical to the Type field of the Attribute format defined in [RFC2865] Section 5.

Length

This field is identical to the Length field of the Attribute format defined in [RFC2865] Section 5. Permitted values are between 5 and 255. If a client or server receives a "Long

Extended Attribute" with a Length of 2, 3, or 4, then that Attribute MUST be considered to be an "invalid attribute", and be handled as per [Section 2.7](#), below.

Extended-Type

This field is identical to the Extended-Type field defined above in [Section 2.1](#).

M (More)

The More field is one (1) bit in length, and indicates whether or not the current attribute contains "more" than 251 octets of data. The More field MUST be clear (0) if the Length field has value less than 255. The More field MAY be set (1) if the Length field has value of 255.

If the More field is set (1), it indicates that the Value field has been fragmented across multiple RADIUS attributes. When the More field is set (1), the attribute SHOULD have a Length field of value 255; it MUST NOT have a length Field of value 4; there MUST be an attribute following this one; and the next attribute MUST have both the same Type and Extended Type. That is, multiple fragments of the same value MUST be in order and MUST be consecutive attributes in the packet, and the last attribute in a packet MUST NOT have the More field set (1).

When the Length field of an attribute has value less than 255, the More field SHOULD be clear (0).

If a client or server receives an attribute fragment with the "More" field set (1), but for which no subsequent fragment can be found, then the fragmented attribute is considered to be an "invalid attribute", and handled as per [Section 2.7](#), below.

Reserved

This field is 7 bits long, and is reserved for future use. Implementations MUST set it to zero (0) when encoding an attribute for sending in a packet. The contents SHOULD be ignored on reception.

Future specifications may define additional meaning for this field. Implementations therefore MUST NOT treat this field as invalid if it is non-zero.

Value

This field is similar to the Value field of the Attribute format defined in [\[RFC2865\] Section 5](#). It may contain a complete set of data (when the Length field has value less than 255), or it may contain a fragment of data (when the More field is set).

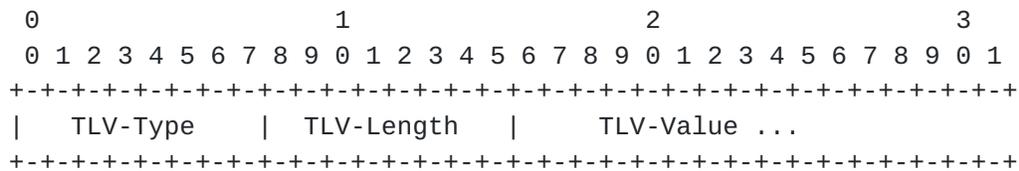
Any interpretation of the resulting data MUST occur after the fragments have been reassembled. The length of the data MUST be taken as the sum of the lengths of the fragments (i.e. Value fields) from which it is constructed. The format of the data SHOULD be a valid RADIUS data type.

This definition increases the RADIUS Attribute Type space as above, but also provides for transport of Attributes which could contain more than 253 octets of data.

2.3. TLV Data Type

We define a new data type in RADIUS, called "tlv". The "tlv" data type is an encapsulation layer which permits the "Value" field of an Attribute to contain new sub-Attributes. These sub-Attributes can in turn contain "Value"s of data type TLV. This capability both extends the attribute space, and permits "nested" attributes to be used. This nesting can be used to encapsulate or group data into one or more logical containers.

The "tlv" data type re-uses the RADIUS attribute format, as given below:



TLV-Type

The Type field is one octet. Up-to-date values of this field are specified according to the policies and rules described in [Section 10](#). Values of zero (0) MUST NOT be used. Values 254-255 are "Reserved" for use by future extensions to RADIUS. The value 26 has no special meaning, and MUST NOT be treated as a Vendor Specific attribute.

As with Extended-Type above, the TLV-Type is meaningful only within the context defined by "Type" fields of the encapsulating Attributes. That is, the field may be thought of as defining a new type space of the form "Type.Extended-Type.TLV-Type". Where TLVs are nested, the type space is of the form "Type.Extended-

Type.TLV-Type.TLV-Type", etc.

A RADIUS server MAY ignore Attributes with an unknown "TLV-Type".

A RADIUS client MAY ignore Attributes with an unknown "TLV-Type".

A RADIUS proxy SHOULD forward Attributes with an unknown "TLV-Type" verbatim.

TLV-Length

The TLV-Length field is one octet, and indicates the length of this TLV including the TLV-Type, TLV-Length and TLV-Value fields. It MUST have a value between 3 and 255. If a client or server receives a TLV with an invalid TLV-Length, then the attribute which encapsulates that TLV MUST be considered to be an "invalid attribute", and handled as per [Section 2.7](#), below.

TLV-Value

The Value field is one or more octets and contains information specific to the Attribute. The format and length of the TLV-Value field is determined by the TLV-Type and TLV-Length fields.

The TLV-Value field SHOULD encapsulate a previously defined RADIUS data type. Using non-standard data types is NOT RECOMMENDED. We note that the TLV-Value field MAY also contain one or more attributes of data type "tlv", which allows for simple grouping and multiple layers of nesting.

The TLV-Value field is limited to containing 253 or fewer octets of data. Specifications which require a TLV to contain more than 253 octets of data are incompatible with RADIUS, and need to be redesigned. Specifications which require the transport of empty Values (i.e. Length = 2) are incompatible with RADIUS, and need to be redesigned.

The TLV-Value field MUST NOT contain data using the "Extended Type" formats defined in this document. The base Extended Attributes format allows for sufficient flexibility that nesting them inside of a TLV offers little additional value.

This TLV definition is compatible with the suggested format of the "String" field of the Vendor-Specific attribute, as defined in [\[RFC2865\] Section 5.26](#), though that specification does not discuss nesting.

Vendors MAY use attributes of type "tlv" in any Vendor Specific

Attribute. We RECOMMEND using type "tlv" for VSAs, in preference to any other format.

2.3.1. TLV Nesting

TLVs may contain other TLVs. When this occurs, the "container" TLV MUST be completely filled by the "contained" TLVs. That is, the "container" TLV-Length field MUST be exactly two (2) more than the sum of the "contained" TLV-Length fields. If the "contained" TLVs over-fill the "container" TLV, the "container" TLV MUST be considered to be an "invalid attribute", and handled as described in [Section 2.7](#), below.

The depth of TLV nesting is limited only by the restrictions on the TLV-Length field. The limit of 253 octets of data results in a limit of 126 levels of nesting. However, nesting depths of more than 4 are NOT RECOMMENDED.

2.4. EVS Data Type

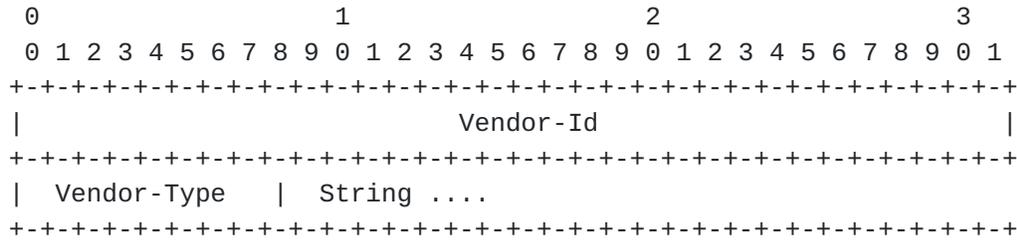
We define a new data type in RADIUS, called "evs", for "Extended Vendor-Specific". The "evs" data type is an encapsulation layer which permits the "Value" field of an Attribute to contain a Vendor-Id, followed by a Vendor-Type, and then vendor-defined data. This data can in turn contain valid RADIUS data types, or any other data as determined by the vendor.

This data type is intended use in attributes which carry Vendor-Specific information, as is done with the Vendor-Specific Attribute (26). It is RECOMMENDED that this data type be used by a vendor only when the Vendor-Specific Attribute Type space has been fully allocated.

Where [\[RFC2865\] Section 5.26](#) makes a recommendation for the format of the data following the Vendor-Id, we give a strict definition. Experience has shown that many vendors have not followed the [\[RFC2865\]](#) recommendations, leading to interoperability issues. We hope here to give vendors sufficient flexibility as to meet their needs, while minimizing the use of non-standard VSA formats.

The "evs" data type MAY be used in Attributes having the format of "Extended Type" or "Long Extended Type". It MUST NOT be used in any other Attribute definition, including standard RADIUS Attributes, TLVs, and VSAs.

A summary of the "evs" data type format is shown below. The fields are transmitted from left to right.



Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. It SHOULD encapsulate a previously defined RADIUS data type. Using non-standard data types is NOT RECOMMENDED. We note that the Value field may be of data type "tlv". However, it MUST NOT be of data type "evs", as the use cases are unclear for one vendor delegating Attribute Type space to another vendor.

The actual format of the information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets. We recognise that Vendors have complete control over the contents and format of the Value field, while at the same time recommending that good practices be followed.

Further codification of the range of allowed usage of this field is outside the scope of this specification.

Note that unlike the format described in [\[RFC2865\] Section 5.26](#), this data type has no "Vendor length" field. The length of the "String" field is implicit, and is determined by taking the "Length" of the encapsulating RADIUS Attribute, and subtracting the length of the attribute header (2 octets), the extended type (1 octet), the Vendor-Id (4 octets), and the Vendor-type (1 octet). i.e. For "Extended Type" attributes, the length of the String field is eight (8) less than the value of the Length field. For "Long Extended Type" attributes, the length of the String field is nine (9) less than the value of the Length field.

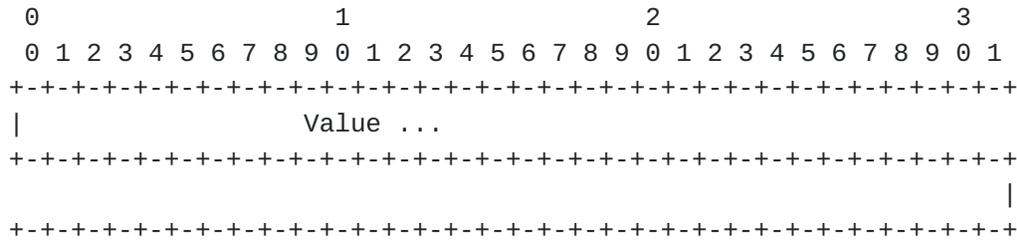
2.5. Integer64 Data Type

We define a new data type in RADIUS, called "integer64", which carries a 64-bit unsigned integer in network byte order.

This data type is intended to be used in any situation where there is a need to have counters which can count past 2^32. The expected use of this data type is within Accounting-Request packets, but this data type SHOULD be used in any packet where 32-bit integers are expected to be insufficient.

The "integer64" data type MAY be used in Attributes of any format, standard space, extended attributes, TLVs, and VSAs.

A summary of the "integer64" data type format is shown below. The fields are transmitted from left to right.



Attributes having data type "integer64" MUST have the relevant Length field set to eight more than the length of the Attribute header. For standard space Attributes and TLVs, this means that the Length field MUST be set to ten (10). For "Extended Type" Attributes, the Length field MUST be set to eleven (11). For "Long Extended Type" Attributes, the Length field MUST be set to twelve (12).

2.6. Vendor-ID Field

We define the Vendor-ID field of Vendor-Specific Attributes to encompass the entire 4 octets of the Vendor field. [RFC2865] Section 5.26 defined it to be 3 octets, with the high octet being zero. This change has no immediate impact on RADIUS, as the maximum Private Enterprise Code defined is still within 16 bits.

However, it is best to make advance preparations for changes in the protocol. As such, it is RECOMMENDED that all implementations support four (4) octets for the Vendor-ID field, instead of three (3).

2.7. Attribute Naming and Type Identifiers

Attributes have traditionally been identified by a unique name and number. For example, the attribute named "User-Name" has been allocated number one (1). This scheme needs to be extended in order to be able to refer to attributes of Extended Type, and to TLVs. It will also be used by IANA for allocating RADIUS Attribute Type values.

The names and identifiers given here are intended to be used only in specifications. The system presented here may not be useful when referring to the contents of a RADIUS packet. It imposes no requirements on implementations, as implementations are free to reference RADIUS Attributes via any method they choose.

2.7.1. Attribute and TLV Naming

RADIUS specifications traditionally use names consisting of one or more words, separated by hyphens, e.g. "User-Name". However, these names are not allocated from a registry, and there is no restriction other than convention on their global uniqueness.

Similarly, vendors have often used their company name as the prefix for VSA names, though this practice is not universal. For example, for a vendor named "Example", the name "Example-Attribute-Name" SHOULD be used instead of "Attribute-Name". The second form can conflict with attributes from other vendors, whereas the first form cannot.

We therefore RECOMMEND that specifications give names to Attributes which attempt to be globally unique across all RADIUS Attributes. We RECOMMEND that vendors use their name as a unique prefix for attribute names. We recognise that these suggestion may sometimes be difficult to implement in practice.

TLVs SHOULD be named with a unique prefix that is shared among related attributes. For example, a specification that defines a set of TLVs related to time could create attributes named "Time-Zone", "Time-Day", "Time-Hour", "Time-Minute", etc.

2.7.2. Attribute Type Identifiers

The RADIUS Attribute Type space defines a context for a particular "Extended-Type" field. The "Extended-Type" field allows for 256 possible type code values, with values 1 through 240 available for allocation. We define here an identification method that uses a "dotted number" notation similar to that used for Object Identifiers (OIDs), formatted as "Type.Extended-Type".

For example, an attribute within the Type space of 241, having Extended-Type of one (1), is uniquely identified as "241.1". Similarly, an attribute within the Type space of 246, having Extended-Type of ten (10), is uniquely identified as "246.10".

The algorithm used to create the Attribute Identifier is simply to concatenate all of the various identification fields (e.g. Type, Extended-Type, etc.), starting from the encapsulating attribute, down to the final encapsulated TLV, separated by a '.' character.

2.7.3. TLV Identifiers

We can extend the Attribute reference scheme defined above for TLVs. This is done by leveraging the "dotted number" notation. As above, we define an additional TLV type space, within the "Extended Type" space, by appending another "dotted number" in order to identify the TLV. This method can be repeated in sequence for nested TLVs.

For example, let us say that "245.1" identifies RADIUS Attribute Type 245, containing an "Extended Type" of one (1), which is of type "tlv". That attribute will contain 256 possible TLVs, one for each value of the TLV-Type field. The first TLV-Type value of one (1) can then be identified by appending a ".1" to the number of the encapsulating attribute ("241.1"), to yield "241.1.1". Similarly, the sequence "245.2.3.4" identifies RADIUS attribute 245, containing an "Extended Type" of two (2) which is of type "tlv", which in turn contains a TLV with TLV-Type number three (3), which in turn contains another TLV, with TLV-Type number four (4).

2.7.4. VSA Identifiers

There has historically been no method for numerically addressing VSAs. The "dotted number" method defined here can also be leveraged to create such an addressing scheme. However, as the VSAs are completely under the control of each individual vendor, this section provides a suggested practice, but does not define a standard of any kind.

The Vendor-Specific Attribute has been assigned the Attribute number 26. It in turn carries a 24-bit Vendor-Id, and possibly additional VSAs. Where the VSAs follow the [\[RFC2865\] Section 5.26](#) recommended format, a VSA can be identified as "26.Vendor-Id"."Vendor-Type".

For example, Livingston has Vendor-Id 307, and has defined an attribute "IP-Pool" as number 6. This VSA can be uniquely identified as 26.307.6.

Note that there is no restriction on the size of the numerical values

in this notation. The Vendor-Id is a 24-bit number, and the VSA may have been assigned from a 16-bit vendor-specific Attribute Type space.

For example, the company USR has been allocated Vendor-Id 429, and has defined a "Version-Id" attribute as number 32768. This VSA can be uniquely identified as 26.429.32768.

Where a VSA is a TLV, the "dotted number" notation can be used as above: 26.VID.VSA.TLV1.TLV2.TLV3 where "TLVn" are the numerical values assigned by the vendor to the different nested TLVs.

2.8. Invalid Attributes

The term "invalid attribute" is new to this specification. It is defined to mean that the Length field of an Attribute is valid (as per [\[RFC2865\], Section 5](#), top of page 25). However, the Value field of the attribute does not follow the format required by the data type defined for that Attribute. e.g. an Attribute of data type "address" which encapsulates more than four, or less than four, octets of data. Or, an IPV6 Prefix attribute which has a Prefix value of more than 128.

While the content of these attributes is malformed, we emphasize that the encapsulating RADIUS packet (or TLV) is well formed, and can be correctly decoded. The existence of an "invalid attribute" in a packet MUST NOT result in the implementation discarding the entire packet, or treating the packet as a negative acknowledgement. Instead, only the "invalid attribute" is treated differently.

When an implementation receives an "invalid attribute", it SHOULD be silently discarded. If it is not discarded, it MUST NOT be handled in the same manner as a well-formed attribute. For example, receiving an Attribute of data type "address" containing more than four, or less than four octets of data means that the Attribute MUST NOT be treated as being of data type "address".

For Attributes of type "Long Extended Type", an Attribute is considered to be an "invalid attribute" when does not match the criteria set out in [Section 2.2](#), above.

For Attributes of type "TLV", an Attribute is considered to be an "invalid attribute" when the TLV-Length field is valid, but the TLV-Value field does not match the criteria for that Attribute. Implementations SHOULD NOT treat the "invalid attribute" property as being transitive. That is, the encapsulating Attribute SHOULD NOT be treated as being an "invalid attribute" if it encapsulates an "invalid attribute".

3. Attribute Definitions

We define four (4) attributes of "Extended Type", which are allocated from the "Reserved" Attribute Type codes of 241, 242, 243, and 244. We also define two (2) attributes of "Long Extended Type", which are allocated from the "Reserved" Attribute Type codes of 245 and 246.

Type	Name
241	Extended-Type-1
242	Extended-Type-2
243	Extended-Type-3
244	Extended-Type-4
245	Long-Extended-Type-1
246	Long-Extended-Type-2

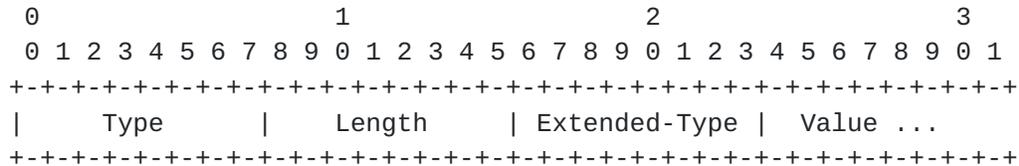
The rest of this section gives a detailed definition for each Attribute based on the above summary.

3.1. Extended-Type-1

Description

This attribute encapsulates attributes of the "Extended Type" format, in the RADIUS Attribute Type Space of 241.{1-255}.

A summary of the Extended-Type-1 Attribute format is shown below. The fields are transmitted from left to right.



Type

241 for Extended-Type-1.

Length

>= 4

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified in the 241.{1-255} RADIUS Attribute Type Space, according to the policies and rules described in Section

10. Further definition of this field is given in [Section 2.1](#), above.

Value

The Value field is one or more octets. Implementations not supporting this specification SHOULD support the field as undistinguished octets.

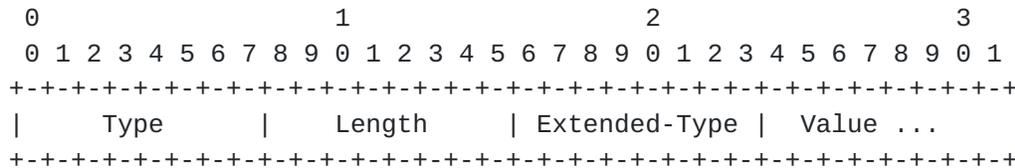
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type" to determine the interpretation of the Value field.

3.2. Extended-Type-2

Description

This attribute encapsulates attributes of the "Extended Type" format, in the RADIUS Attribute Type Space of 242.{1-255}.

A summary of the Extended-Type-2 Attribute format is shown below. The fields are transmitted from left to right.



Type

242 for Extended-Type-2.

Length

>= 4

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified in the 242.{1-255} RADIUS Attribute Type Space, according to the policies and rules described in [Section 10](#). Further definition of this field is given in [Section 2.1](#), above.

Value

The Value field is one or more octets. Implementations not supporting this specification SHOULD support the field as undistinguished octets.

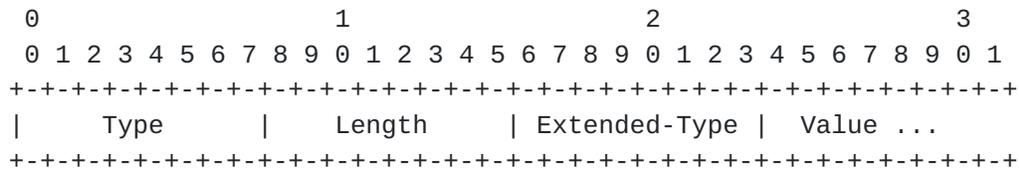
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type" to determine the interpretation of the Value field

3.3. Extended-Type-3

Description

This attribute encapsulates attributes of the "Extended Type" format, in the RADIUS Attribute Type Space of 243.{1-255}.

A summary of the Extended-Type-3 Attribute format is shown below. The fields are transmitted from left to right.



Type

243 for Extended-Type-3.

Length

>= 4

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified in the 243.{1-255} RADIUS Attribute Type Space, according to the policies and rules described in [Section 10](#). Further definition of this field is given in [Section 2.1](#), above.

Value

The Value field is one or more octets. Implementations not supporting this specification SHOULD support the field as undistinguished octets.

Implementations supporting this specification MUST use the

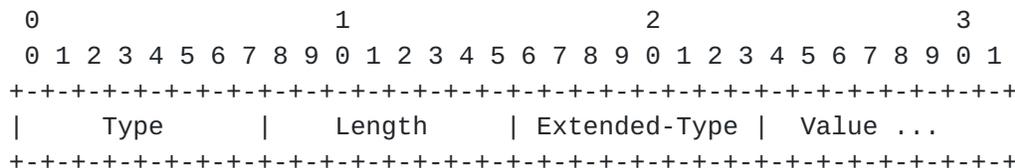
Identifier of "Type.Extended-Type" to determine the interpretation of the Value field.

3.4. Extended-Type-4

Description

This attribute encapsulates attributes of the "Extended Type" format, in the RADIUS Attribute Type Space of 244.{1-255}.

A summary of the Extended-Type-4 Attribute format is shown below. The fields are transmitted from left to right.



Type

244 for Extended-Type-4.

Length

>= 4

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified in the 244.{1-255} RADIUS Attribute Type Space, according to the policies and rules described in [Section 10](#). Further definition of this field is given in [Section 2.1](#), above.

Value

The Value field is one or more octets. Implementations not supporting this specification SHOULD support the field as undistinguished octets.

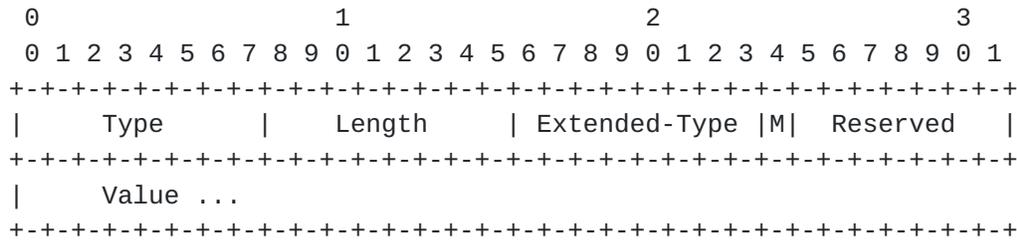
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type" to determine the interpretation of the Value Field.

3.5. Long-Extended-Type-1

Description

This attribute encapsulates attributes of the "Long Extended Type" format, in the RADIUS Attribute Type Space of 245.{1-255}.

A summary of the Long-Extended-Type-1 Attribute format is shown below. The fields are transmitted from left to right.



Type

245 for Long-Extended-Type-1

Length

>= 5

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified in the 245.{1-255} RADIUS Attribute Type Space, according to the policies and rules described in [Section 10](#). Further definition of this field is given in [Section 2.1](#), above.

M (More)

The More field is one (1) bit in length, and indicates whether or not the current attribute contains "more" than 251 octets of data. Further definition of this field is given in [Section 2.2](#), above.

Reserved

This field is 7 bits long, and is reserved for future use. Implementations MUST set it to zero (0) when encoding an attribute for sending in a packet. The contents SHOULD be ignored on reception.

Value

The Value field is one or more octets. Implementations not supporting this specification SHOULD support the field as undistinguished octets.

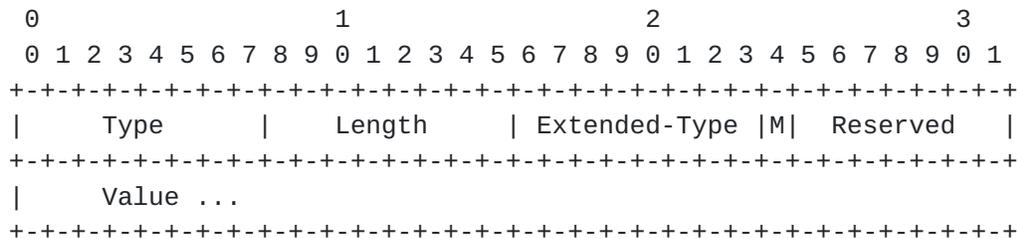
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type" to determine the interpretation of the Value field.

3.6. Long-Extended-Type-2

Description

This attribute encapsulates attributes of the "Long Extended Type" format, in the RADIUS Attribute Type Space of 246.{1-255}.

A summary of the Long-Extended-Type-2 Attribute format is shown below. The fields are transmitted from left to right.



Type

246 for Long-Extended-Type-2

Length

>= 5

Extended-Type

The Extended-Type field is one octet. Up-to-date values of this field are specified in the 246.{1-255} RADIUS Attribute Type Space, according to the policies and rules described in [Section 10](#). Further definition of this field is given in [Section 2.1](#), above.

M (More)

The More field is one (1) bit in length, and indicates whether or not the current attribute contains "more" than 251 octets of data. Further definition of this field is given in [Section 2.2](#), above.

Reserved

This field is 7 bits long, and is reserved for future use. Implementations MUST set it to zero (0) when encoding an attribute for sending in a packet. The contents SHOULD be ignored on reception.

Value

The Value field is one or more octets. Implementations not supporting this specification SHOULD support the field as undistinguished octets.

Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type" to determine the interpretation of the Value field.

4. Vendor Specific Attributes

We define six new attributes which can carry Vendor Specific information. We define four (4) attributes of the "Extended Type" format, with Type codes (241.26, 242.26, 243.26, 244.26), using the "evs" data type. We also define two (2) attributes using "Long Extended Type" format, with Type codes (245.26, 246.26), which are of the "evs" data type.

Type.Extended-Type	Name
-----	----
241.26	Extended-Vendor-Specific-1
242.26	Extended-Vendor-Specific-2
243.26	Extended-Vendor-Specific-3
244.26	Extended-Vendor-Specific-4
245.26	Extended-Vendor-Specific-5
246.26	Extended-Vendor-Specific-6

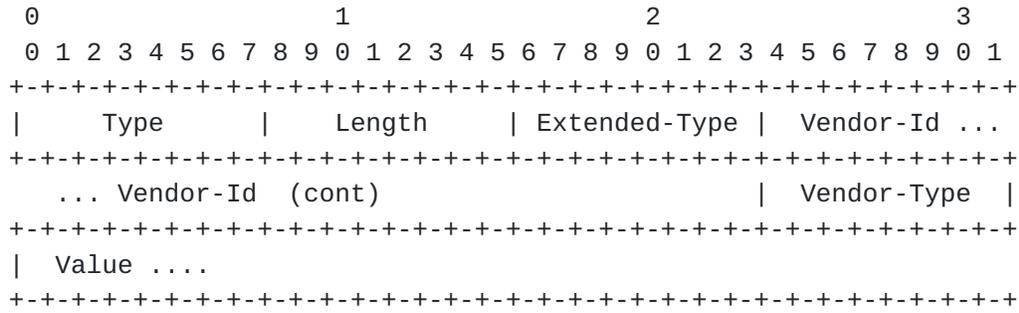
The rest of this section gives a detailed definition for each Attribute based on the above summary.

4.1. Extended-Vendor-Specific-1

Description

This attribute defines a RADIUS Type Code of 241.26, using the "evs" data type.

A summary of the Extended-Vendor-Specific-1 Attribute format is shown below. The fields are transmitted from left to right.



Type.Extended-Type

241.26 for Extended-Vendor-Specific-1

Length

>= 9

Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. The actual format of the information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets.

The codification of the range of allowed usage of this field is outside the scope of this specification.

The length of the Value field is eight (8) less then the value of the Length field.

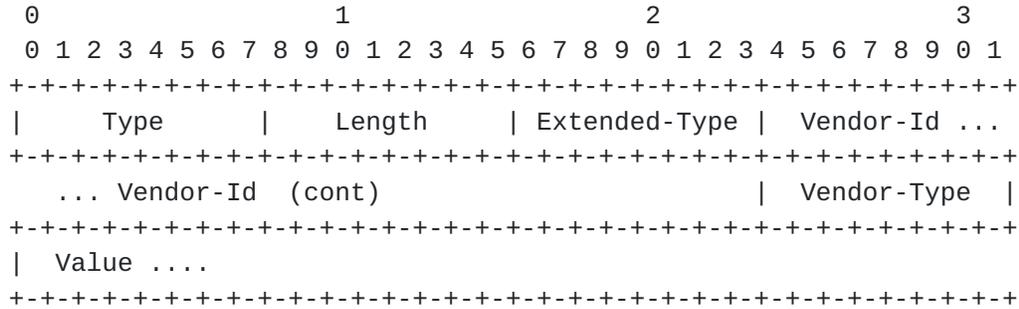
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type.Vendor-Id.Vendor-Type" to determine the interpretation of the Value field.

4.2. Extended-Vendor-Specific-2

Description

This attribute defines a RADIUS Type Code of 242.26, using the "evs" data type.

A summary of the Extended-Vendor-Specific-2 Attribute format is shown below. The fields are transmitted from left to right.



Type.Extended-Type

242.26 for Extended-Vendor-Specific-2

Length

>= 9

Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. The actual format of the information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets.

The codification of the range of allowed usage of this field is outside the scope of this specification.

The length of the Value field is eight (8) less than the value of the Length field.

Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type.Vendor-Id.Vendor-Type" to

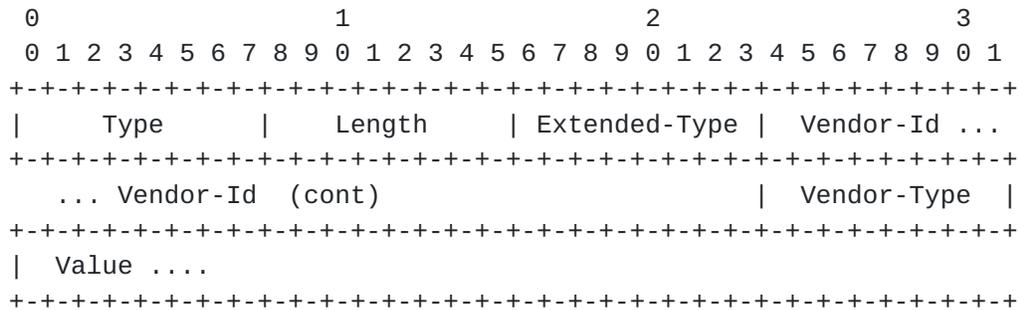
determine the interpretation of the Value field.

4.3. Extended-Vendor-Specific-3

Description

This attribute defines a RADIUS Type Code of 243.26, using the "evs" data type.

A summary of the Extended-Vendor-Specific-3 Attribute format is shown below. The fields are transmitted from left to right.



Type.Extended-Type

243.26 for Extended-Vendor-Specific-3

Length

>= 9

Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. The actual format of the information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets.

The codification of the range of allowed usage of this field is outside the scope of this specification.

The length of the Value field is eight (8) less then the value of the Length field.

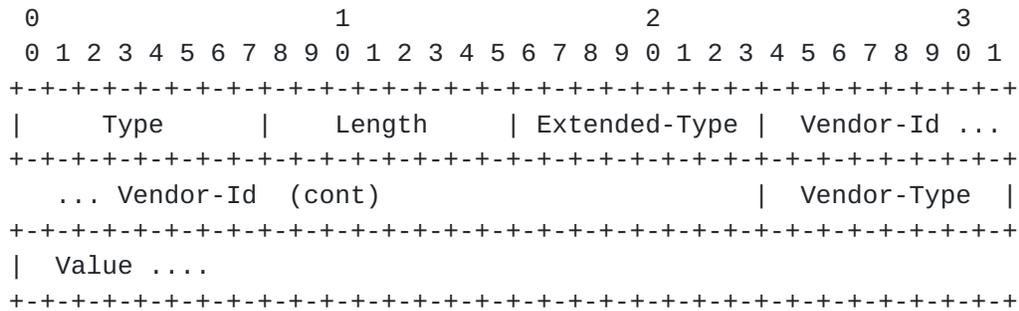
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type.Vendor-Id.Vendor-Type" to determine the interpretation of the Value field.

4.4. Extended-Vendor-Specific-4

Description

This attribute defines a RADIUS Type Code of 244.26, using the "evs" data type.

A summary of the Extended-Vendor-Specific-3 Attribute format is shown below. The fields are transmitted from left to right.



Type.Extended-Type

244.26 for Extended-Vendor-Specific-4

Length

>= 9

Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. The actual format of the

information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets.

The codification of the range of allowed usage of this field is outside the scope of this specification.

The length of the Value field is eight (8) less then the value of the Length field.

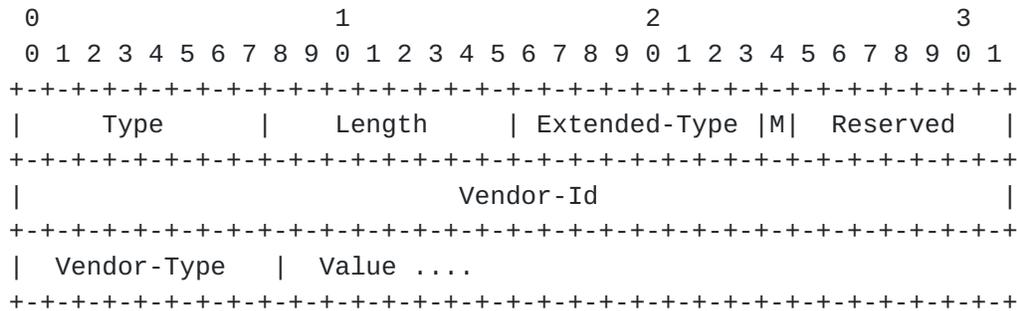
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type.Vendor-Id.Vendor-Type" to determine the interpretation of the Value field.

4.5. Extended-Vendor-Specific-5

Description

This attribute defines a RADIUS Type Code of 245.26, using the "evs" data type.

A summary of the Extended-Vendor-Specific-5 Attribute format is shown below. The fields are transmitted from left to right.



Type.Extended-Type

245.26 for Extended-Vendor-Specific-5

Length

- >= 10 (first fragment)
- >= 5 (subsequent fragments)

When a VSA is fragmented across multiple Attributes, only the first Attribute contains the Vendor-Id and Vendor-Type fields. Subsequent Attributes contain fragments of the Value field only.

M (More)

The More field is one (1) bit in length, and indicates whether or not the current attribute contains "more" than 251 octets of data. Further definition of this field is given in [Section 2.2](#), above.

Reserved

This field is 7 bits long, and is reserved for future use. Implementations MUST set it to zero (0) when encoding an attribute for sending in a packet. The contents SHOULD be ignored on reception.

Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. The actual format of the information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets.

The codification of the range of allowed usage of this field is outside the scope of this specification.

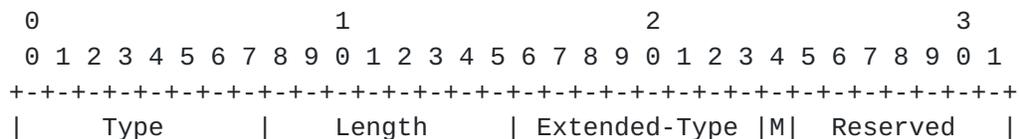
Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type.Vendor-Id.Vendor-Type" to determine the interpretation of the Value field.

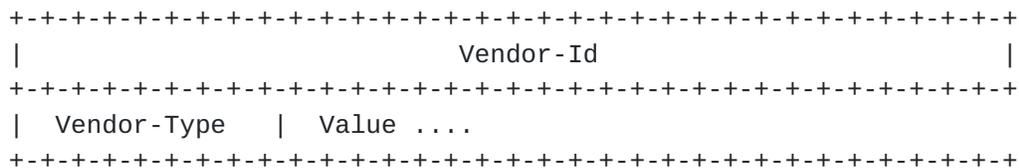
4.6. Extended-Vendor-Specific-6

Description

This attribute defines a RADIUS Type Code of 246.26, using the "evs" data type.

A summary of the Extended-Vendor-Specific-6 Attribute format is shown below. The fields are transmitted from left to right.





Type.Extended-Type

246.26 for Extended-Vendor-Specific-6

Length

- >= 10 (first fragment)
- >= 5 (subsequent fragments)

When a VSA is fragmented across multiple Attributes, only the first Attribute contains the Vendor-Id and Vendor-Type fields. Subsequent Attributes contain fragments of the Value field only.

M (More)

The More field is one (1) bit in length, and indicates whether or not the current attribute contains "more" than 251 octets of data. Further definition of this field is given in [Section 2.2](#), above.

Reserved

This field is 7 bits long, and is reserved for future use. Implementations MUST set it to zero (0) when encoding an attribute for sending in a packet. The contents SHOULD be ignored on reception.

Vendor-Id

The 4 octets are the SMI Network Management Private Enterprise Code of the Vendor in network byte order.

Vendor-Type

The Vendor-Type field is one octet. Values are assigned at the sole discretion of the Vendor.

Value

The Value field is one or more octets. The actual format of the information is site or application specific, and a robust implementation SHOULD support the field as undistinguished octets.

The codification of the range of allowed usage of this field is outside the scope of this specification.

Implementations supporting this specification MUST use the Identifier of "Type.Extended-Type.Vendor-Id.Vendor-Type" to determine the interpretation of the Value field.

5. Compatibility with traditional RADIUS

There are a number of potential compatibility issues with traditional RADIUS, as defined in [[RFC6158](#)] and earlier. This section describes them.

5.1. Attribute Allocation

Some vendors have used Attribute Type codes from the "Reserved" space, as part of vendor-defined dictionaries. This practice is considered anti-social behavior, as noted in [[RFC6158](#)]. These vendor definitions conflict with the attributes in the RADIUS Attribute Type space. The conflicting definitions may make it difficult for implementations to support both those Vendor Attributes, and the new Extended Attribute formats.

We RECOMMEND that RADIUS client and server implementations delete all references to these improperly defined attributes. Failing that, we RECOMMEND that RADIUS server implementations have a per-client configurable flag which indicates which type of attributes are being sent from the client. If the flag is set to "Non-Standard Attributes", the conflicting attributes can be interpreted as being improperly defined Vendor Specific Attributes. If the flag is set the "IETF Attributes", the attributes MUST be interpreted as being of the Extended Attributes format. The default SHOULD be to interpret the attributes as being of the Extended Attributes format.

Other methods of determining how to decode the attributes into a "correct" form are NOT RECOMMENDED. Those methods are likely to be fragile and prone to error.

We RECOMMEND that RADIUS server implementations re-use the above flag to determine which type of attributes to send in a reply message. If the request is expected to contain the improperly defined attributes, the reply SHOULD NOT contain Extended Attributes. If the request is expected to contain Extended Attributes, the reply MUST NOT contain the improper Attributes.

RADIUS clients will have fewer issues than servers. Clients MUST NOT send improperly defined Attributes in a request. For replies, clients MUST interpret attributes as being of the Extended Attributes

format, instead of the improper definitions. These requirements impose no change in the RADIUS specifications, as such usage by vendors has always been in conflict with the standard requirements and the standards process.

Existing clients that send these improperly defined attributes usually have a configuration setting which can disable this behavior. We RECOMMEND that vendors ship products with the default set to "disabled". We RECOMMEND that administrators set this flag to "disabled" on all equipment that they manage.

5.2. Proxy Servers

RADIUS Proxy servers will need to forward Attributes having the new format, even if they do not implement support for the encoding and decoding of those attributes. We remind implementors of the following text in [\[RFC2865\] Section 2.3](#):

The forwarding server MUST NOT change the order of any attributes of the same type, including Proxy-State.

This requirement solves some of the issues related to proxying of the new format, but not all. The reason is that proxy servers are permitted to examine the contents of the packets that they forward. Many proxy implementations not only examine the attributes, but they refuse to forward attributes which they do not understand (i.e. attributes for which they have no local dictionary definitions).

This practice is NOT RECOMMENDED. Proxy servers SHOULD forward attributes, even ones which they do not understand, or which are not in a local dictionary. When forwarded, these attributes SHOULD be sent verbatim, with no modifications or changes. The only exception to this recommendation is when local site policy dictates that filtering of attributes has to occur. For example, a filter at a visited network may require removal of certain authorization rules which apply to the home network, but not to the visited network. This filtering can sometimes be done even when the contents of the attributes are unknown, such as when all Vendor-Specific Attributes are designated for removal.

As seen in [\[EDUROAM\]](#) many proxies do not follow these practices for unknown Attributes. Some proxies filter out unknown attributes or attributes which have unexpected lengths (24%, 17/70), some truncate the attributes to the "expected" length (11%, 8/70), some discard the request entirely (1%, 1/70), with the rest (63%, 44/70) following the recommended practice of passing the attributes verbatim. It will be difficult to widely use the Extended Attributes format until all non-conformant proxies are fixed. We therefore RECOMMEND that all

proxies which do not support the Extended Attributes (241 through 246) define them as being of data type "string", and delete all other local definitions for those attributes.

This last change should enable wider usage of the Extended Attributes format.

6. Guidelines

This specification proposes a number of changes to RADIUS, and therefore requires a set of guidelines, as has been done in [\[RFC6158\]](#).

6.1. Updates to [RFC 6158](#)

This specification updates [\[RFC6158\]](#) by adding the data types "evs", "tlv" and "integer64"; defining them to be "basic" data types; and permitting their use subject to the restrictions outlined below.

The recommendations for the use of the new data types and attribute formats are given below. All other recommendations given in [\[RFC6158\]](#) are unchanged.

6.2. Guidelines for Simple Data Types

[\[RFC6158\]](#) Section A.2.1 says in part:

- * Unsigned integers of size other than 32 bits.
SHOULD be replaced by an unsigned integer of 32 bits. There is insufficient justification to define a new size of integer.

We update that specification to permit unsigned integers of 64 bits, for the reasons defined above in [Section 2.5](#). The updated text is as follows:

- * Unsigned integers of size other than 32 or 64 bits.
SHOULD be replaced by an unsigned integer of 32 or 64 bits.
There is insufficient justification to define a new size of integer.

That section later continues with the following list item:

- * Nested attribute-value pairs (AVPs).
Attributes should be defined in a flat typespace.

We update that specification to permit nested TLVs, as defined in this document:

- * Nested attribute-value pairs (AVPs) using the extended attribute format MAY be used. All other nested AVP or TLV formats MUST NOT be used.

6.3. Guidelines for Complex Data Types

[RFC6158] [Section 2.1](#) says:

Complex data types MAY be used in situations where they reduce complexity in non-RADIUS systems or where using the basic data types would be awkward (such as where grouping would be required in order to link related attributes).

Since the extended attribute format allows for grouping of complex types via TLVs, the guidelines for complex data types need to be updated as follows:

Complex data types MAY be used where they reduce complexity in non-RADIUS systems, though this practice is NOT RECOMMENDED. The complex data type exceptions of [\[RFC6158\] Section 3.2.4](#) still apply. In all other situations, complex data types MUST NOT be used. Instead, complex data types MUST be decomposed into TLVs, using the extended attribute format.

The checklist in [Appendix A.2.2](#) is similarly updated to add a new requirement at the top of that section,

Does the attribute:

- * define a complex type which can be represented via TLVs?

If so, this data type MUST be represented via TLVs.

Note that this requirement does not over-ride Section A.1, which permits the transport of complex types in certain situations.

6.4. Guidelines For the New Types

We recommend the following guidelines when designing attributes using the new format. The items listed below are not exhaustive. As experience is gained with the new formats, later specifications may define additional guidelines.

- * The data type "evs" MUST NOT be used for standard RADIUS

Attributes, or for TLVs, or for VSAs.

- * The data type "tlv" SHOULD NOT be used for standard RADIUS attributes. While its use is NOT RECOMMENDED by [[RFC6158](#)], this specification updates [[RFC6158](#)] to permit the "tlv" data type in attributes using the Extended-Type format.
- * [[RFC2866](#)] "tagged" attributes MUST NOT be defined in the Extended-Type space. The "tlv" data type should be used instead to group attributes.
- * The "integer64" data type MAY be used in any RADIUS attribute. The use of 64-bit integers is NOT RECOMMENDED by [[RFC6158](#)], but their utility is now evident.
- * Any attribute which is allocated from the Type spaces of 245.* or 246.*, of data type "text", "string", or "tlv" can end up carrying more than 251 octets of data, up to the maximum RADIUS packet length (~4096 octets). Specifications defining such attributes SHOULD define a maximum length.
- * For all other circumstances, the guidelines in [[RFC6158](#)] MUST be followed.

[6.5.](#) Allocation Request Guidelines

The following items give guidelines for allocation requests made in a RADIUS specification.

- * Discretion is RECOMMENDED when requesting allocation of attributes. The new space is much larger than the old one, but it is not infinite.
- * Specifications which request ten (10) or more attributes MUST NOT request that all be allocated from the standard space. That space is under allocation pressure, and the extended space is more suitable for large allocations.
- * New specifications SHOULD NOT request allocation from the standard Attribute Type Space (i.e. Attributes 1 through 255). That space is deprecated.
- * It is RECOMMENDED that specifications do not request allocation from a specific space. The IANA considerations given in [Section 9](#), below, should be sufficient for attribute allocation.
- * Specifications of an attribute which encodes 252 octets or less

of data MAY request allocation from the extended space, using format "Extended Type"

- * Specifications of an attribute which can always encode less than 253 octets of data MUST NOT request allocation from the long extended space. The standard space, or the short extended space MUST be used instead.
- * Specifications of an attribute which encodes 253 octets or more of data MUST request allocation from the long extended space.
- * When the extended space is nearing exhaustion, a new specification SHOULD be written which requests allocation of one or more RADIUS Attributes from the "Reserved" portion of the standard space, values 247-255, using an appropriate format ("Extended Type", or "Long Extended Type")

6.6. TLV Guidelines

The following items give guidelines for specifications using TLVs.

- * when multiple attributes are intended to be grouped or managed together, the use of TLVs to group related attributes is RECOMMENDED.
- * more than 4 layers (depth) of TLV nesting is NOT RECOMMENDED.
- * Interpretation of an attribute depends only on its type definition (e.g. Type.Extended-Type.TLV-Type), and not on its encoding or location in the RADIUS packet.
- * Where a group of TLVs is strictly defined, and not expected to change, and totals less than 247 octets of data, they SHOULD request allocation from the Type spaces of 241.*, 242.*, 243.*, or 244.*.
- * Where a group of TLVs is loosely defined, or is expected to change, they SHOULD request allocation from the Type spaces of 245.* or 246.*.

6.7. Implementation Guidelines

- * RADIUS client implementations SHOULD support this specification, in order to permit the easy deployment of specifications using the changes defined herein.
- * RADIUS server implementations SHOULD support this specification, in order to permit the easy deployment of specifications using

the changes defined herein.

- * RADIUS proxy servers SHOULD forward all attributes, even ones which they do not understand, or which are not in a local dictionary. These attributes SHOULD be forwarded verbatim, with no modifications or changes.
- * When forwarding attributes, RADIUS proxy servers SHOULD forward the "Reserved" field unchanged. That is, they SHOULD NOT assume that the "Reserved" field can always be set to zero.

6.8. Vendor Guidelines

- * Vendors SHOULD use the existing Vendor-Specific Attribute Type space in preference to the new Extended-Vendor-Specific attributes, as this specification may take time to become widely deployed.
- * Vendors SHOULD implement this specification. The changes to RADIUS are relatively small, and are likely to quickly be used in new specifications.

7. Rationale

The path to extending the RADIUS protocol has been long and arduous. A number of proposals have been made and discarded by the RADEXT working group. These proposals have been judged to be either too bulky, too complex, too simple, or to be unworkable in practice. We do not otherwise explain here why earlier proposals did not obtain working group consensus.

The changes outlined here have the benefit of being simple, as the "Extended Type" format requires only a one octet change to the Attribute format. The downside is that the "Long Extended Type" format is awkward, and the 7 Reserved bits will likely never be used for anything.

7.1. Attribute Audit

An audit of almost five thousand publicly available attributes [[ATTR](#)], shows the statistics summarized below. The attributes include over 100 Vendor dictionaries, along with the IANA assigned attributes:

Count	Data Type
-----	-----
2257	integer
1762	text

273	IPv4 Address
225	string
96	other data types
35	IPv6 Address
18	date
10	integer64
4	Interface Id
3	IPv6 Prefix
4683	Total

The entries in the "Data Type" column are data types recommended by [[RFC6158](#)], along with "integer64". The "other data types" row encompasses all other data types, including complex data types and data types transporting opaque data.

We see that over half of the attributes encode less than 16 octets of data. It is therefore important to have an extension mechanism which adds as little as possible to the size of these attributes. Another result is that the overwhelming majority of attributes use simple data types.

Of the attributes defined above, 177 were declared as being inside of a TLV. This is approximately 4% of the total. We did not investigate whether additional attributes were defined in a flat name space, but could have been defined as being inside of a TLV. We expect that the number could be as high as 10% of attributes.

Manual inspection of the dictionaries shows that approximately 20 (or 0.5%) attributes have the ability to transport more than 253 octets of data. These attributes are divided between VSAs, and a small number of standard Attributes such as EAP-Message.

The results of this audit and analysis is reflected in the design of the extended attributes. The extended format has minimal overhead, it permits TLVs, and it has support for "long" attributes.

8. Diameter Considerations

The attribute formats defined in this specification need to be transported in Diameter. While Diameter supports attributes longer than 253 octets and grouped attributes, we do not use that functionality here. Instead, we define the simplest possible encapsulation method.

The new formats MUST be treated the same as traditional RADIUS attributes when converting from RADIUS to Diameter, or vice versa. That is, the new attribute space is not converted to any "extended"

Diameter attribute space. Fragmented attributes are not converted to a single long Diameter attribute. The new EVS data types are not converted to Diameter attributes with the "V" bit set.

In short, this document mandates no changes for existing RADIUS to Diameter, or Diameter to RADIUS gateways.

9. Examples

A few examples are presented here in order to illustrate the encoding of the new attribute formats. These examples are not intended to be exhaustive, as many others are possible. For simplicity, we do not show complete packets, only attributes.

The examples are given using a domain-specific language implemented by the program given in [Appendix A](#). The language is line oriented, and composed of a sequence of lines matching the grammar ([\[RFC5234\]](#)) given below:

```
Identifier = 1*DIGIT *( "." 1*DIGIT )
```

```
HEXCHAR = HEXDIG HEXDIG
```

```
STRING = DQUOTE 1*CHAR DQUOTE
```

```
TLV = "{" 1*DIGIT DATA "}"
```

```
DATA = 1*HEXCHAR / 1*TLV / STRING
```

```
LINE = Identifier DATA
```

The program has additional restrictions on its input that are not reflected in the above grammar. For example, the portions of the Identifier which refer to Type and Extended-Type are limited to values between 1 and 255. We trust that the source code in [Appendix A](#) is clear, and that these restrictions do not negatively affect the comprehensibility of the examples.

The program reads the input text, and interprets it as a set of instructions to create RADIUS Attributes. It then prints the hex encoding of those attributes. It implements the minimum set of functionality which achieves that goal. This minimalism means that it does not use attribute dictionaries; it does not implement support for RADIUS data types; it can be used to encode attributes with invalid data fields; and there is no requirement for consistency from one example to the next. For example, it can be used to encode a User-Name attribute which contains non-UTF8 data, or a Framed-IP-Address which contains 253 octets of ASCII data. As a result, it

MUST NOT be used to create RADIUS Attributes for transport in a RADIUS message.

However, the program correctly encodes the RADIUS attribute fields of "Type", "Length", "Extended-Type", "More", "Reserved", "Vendor-Id", "Vendor-Type", and "Vendor-Length". It encodes RADIUS attribute data types "evs" and TLV. It can therefore be used to encode example attributes from inputs which are humanly readable.

We do not give examples of "malformed" or "invalid attributes". We also note that the examples show format, rather than consistent meaning. A particular Attribute Type code may be used to demonstrate two different formats. In real specifications, attributes have a static definitions based on their type code.

The examples given below are strictly for demonstration purposes only, and do not provide a standard of any kind.

9.1. Extended Type

The following are a series of examples of the "Extended Type" format.

Attribute encapsulating textual data.

```
241.1 "bob"
-> f1 06 01 62 6f 62
```

Attribute encapsulating a TLV with TLV-Type of one (1).

```
241.2 { 1 23 45 }
-> f1 07 02 01 04 23 45
```

Attribute encapsulating two TLVs, one after the other.

```
241.2 { 1 23 45 } { 2 67 89 }
-> f1 0b 02 01 04 23 45 02 04 67 89
```

Attribute encapsulating two TLVs, where the second TLV is itself encapsulating a TLV.

```
241.2 { 1 23 45 } { 3 { 1 ab cd } }
-> f1 0d 02 01 04 23 45 03 06 01 04 ab cd
```

Attribute encapsulating two TLVs, where the second TLV is itself encapsulating two TLVs.

```
241.2 { 1 23 45 } { 3 { 1 ab cd } { 2 "foo" } }
-> f1 12 02 01 04 23 45 03 0b 01 04 ab cd 02 05 66 6f 6f
```


Attribute encapsulating a TLV, which in turn encapsulates a TLV, to a depth of 5 nestings.

```
241.1 { 1 { 2 { 3 { 4 { 5 cd ef } } } } }
-> f1 0f 01 01 0c 02 0a 03 08 04 06 05 04 cd ef
```

Attribute encapsulating an extended Vendor Specific attribute, with Vendor-Id of 1, and Vendor-Type of 4, which in turn encapsulates textual data.

```
241.26.1.4 "test"
-> f1 0c 1a 00 00 00 01 04 74 65 73 74
```

Attribute encapsulating an extended Vendor Specific attribute, with Vendor-Id of 1, and Vendor-Type of 5, which in turn encapsulates a TLV with TLV-Type of 3, which encapsulates textual data.

```
241.26.1.5 { 3 "test" }
-> f1 0e 1a 00 00 00 01 05 03 06 74 65 73 74
```

9.2. Long Extended Type

The following are a series of examples of the "Long Extended Type" format.

Attribute encapsulating textual data.

```
245.1 "bob"
-> f5 07 01 00 62 6f 62
```

Attribute encapsulating a TLV with TLV-Type of one (1).

```
245.2 { 1 23 45 }
-> f5 08 02 00 01 04 23 45
```

Attribute encapsulating two TLVs, one after the other.

```
245.2 { 1 23 45 } { 2 67 89 }
-> f5 0c 02 00 01 04 23 45 02 04 67 89
```

Attribute encapsulating two TLVs, where the second TLV is itself encapsulating a TLV.

```
245.2 { 1 23 45 } { 3 { 1 ab cd } }
-> f5 0e 02 00 01 04 23 45 03 06 01 04 ab cd
```

Attribute encapsulating two TLVs, where the second TLV is itself


```

bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb f5 13 04 00 cc
cc cc cc cc cc cc cc cc cc cc cc cc cc cc cc

```

Attribute encapsulating an extended Vendor Specific attribute, with Vendor-Id of 1, and Vendor-Type of 6, which in turn encapsulates more than 251 octets of data.

As the VSA encapsulates more than 251 octets of data, it is split into two RADIUS attributes. The first attribute has the More field set, and carries the Vendor-Id and Vendor-Type. The second attribute has the More field clear, and carries the rest of the data portion of the VSA. Note that the second attribute does not include the Vendor-Id and Vendor-Type fields.

The "Data" portions are indented for readability.

```

245.26.1.6 aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaabbbbbbbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb
cccccccccccccccccc
-> f5 ff 1a 80 00 00 00 01 06 aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa
aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa ab bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb
bb bb bb bb bb bb bb bb bb bb bb bb bb bb bb f5 17 1a 00 bb
bb bb bb bb cc 13 45 67 89

```


10. IANA Considerations

This document updates [[RFC3575](#)] in that it adds new IANA considerations for RADIUS Attributes. These considerations modify and extend the IANA considerations for RADIUS, rather than replacing them.

The IANA considerations of this document are limited to the "RADIUS Attribute Types" registry. Some Attribute Type values which were previously marked "Reserved" are now allocated, and the registry is extended from a simple 8-bit array to a tree-like structure, up to a maximum depth of 125 nodes. Detailed instructions are given below.

10.1. Attribute Allocations

IANA is requested to move the following Attribute Type values from "Reserved", to "Allocated", with the corresponding names:

- * 241 Extended-Type-1
- * 242 Extended-Type-2
- * 243 Extended-Type-3
- * 244 Extended-Type-4
- * 245 Long-Extended-Type-1
- * 246 Long-Extended-Type-2

These values serve as an encapsulation layer for the new RADIUS Attribute Type tree.

10.2. RADIUS Attribute Type Tree

Each of the Attribute Type values allocated above extends the "RADIUS Attribute Types" to an N-ary tree, via a "dotted number" notation. Allocation of an Attribute Type value "TYPE" using the new Extended type format results in allocation of 255 new Attribute Type values, of format "TYPE.1" through "TYPE.255". The value zero "TYPE.0" is not used. Value twenty-six (26) is assigned as "Extended-Vendor-Specific-*". Values "TYPE.241" through "TYPE.255" are marked "Reserved". All other values are "Unassigned".

The initial set of Attribute Type values and names assigned by this document is given below.

- * 241 Extended-Attribute-1
- * 241.{1-25} Unassigned
- * 241.26 Extended-Vendor-Specific-1
- * 241.{27-240} Unassigned
- * 241.{241-255} Reserved

* 242	Extended-Attribute-2
* 242.{1-25}	Unassigned
* 242.26	Extended-Vendor-Specific-2
* 242.{27-240}	Unassigned
* 243	Extended-Attribute-3
* 242.{241-255}	Reserved
* 243.{1-25}	Unassigned
* 243.26	Extended-Vendor-Specific-3
* 243.{27-240}	Unassigned
* 243.{241-255}	Reserved
* 244	Extended-Attribute-4
* 244.{1-25}	Unassigned
* 244.26	Extended-Vendor-Specific-4
* 244.{27-240}	Unassigned
* 244.{241-255}	Reserved
* 245	Extended-Attribute-5
* 245.{1-25}	Unassigned
* 245.26	Extended-Vendor-Specific-5
* 245.{27-240}	Unassigned
* 245.{241-255}	Reserved
* 246	Extended-Attribute-6
* 246.{1-25}	Unassigned
* 245.26	Extended-Vendor-Specific-6
* 246.{27-240}	Unassigned
* 246.{241-255}	Reserved

As per [[RFC5226](#)], the values marked "Unassigned" above are available via for assignment by IANA in future RADIUS specifications. The values marked "Reserved" are reserved for future use.

The Extended-Vendor-Specific spaces (TYPE.26) are for Private Use, and allocations are not managed by IANA.

Allocation of Reserved entries in the extended space requires Standards Action.

All other allocations in the extended space require IETF Review.

10.3. Allocation Instructions

This section defines what actions IANA needs to take when allocating new attributes. Different actions are required when allocating attributes from the standard space, attributes of Extended Type format, attributes of the "Long Extended Type" format, preferential allocations, attributes of data type TLV, attributes within a TLV, and attributes of other data types.

10.3.1. Requested Allocation from the Standard Space

Specifications can request allocation of an Attribute from within the standard space (e.g. Attribute Type Codes 1 through 255), subject to the considerations of [[RFC3575](#)] and this document.

10.3.2. Requested Allocation from the short extended space

Specifications can request allocation of an Attribute which requires the format Extended Type, by specifying the short extended space. In that case, IANA should assign the lowest Unassigned number from the Attribute Type space with the relevant format.

10.3.3. Requested Allocation from the long extended space

Specifications can request allocation of an Attribute which requires the format "Long Extended Type", by specifying the extended space (long). In that case, IANA should assign the lowest Unassigned number from the Attribute Type space with the relevant format.

10.3.4. Allocation Preferences

Specifications which make no request for allocation from a specific Type Space should have Attributes allocated using the following criteria:

- * when the standard space has no more Unassigned attributes, all allocations should be performed from the extended space.
- * specifications which allocate a small number of attributes (i.e. less than ten) should have all allocations made from the standard space.
- * specifications which allocate a large number of attributes (i.e. ten or more) should have all allocations made from the extended space.
- * specifications which request allocation of an Attribute of data type TLV should have that attribute allocated from the extended space.
- * specifications which request allocation of an attribute which can transport 253 or more octets of data should have that attribute allocated from within the long extended space, We note that [Section 6.5](#), above requires specifications to request this allocation.

There is otherwise no requirement that all attributes within a

specification be allocated from one type space or another. Specifications can simultaneously allocate attributes from both the standard space and the extended space.

10.3.5. Extending the Type Space via TLV Data Type

When specifications request allocation of an attribute of data type "tlv", that allocation extends the Attribute Type Tree by one more level. Allocation of an Attribute Type value "TYPE.TLV", with Data Type TLV, results in allocation of 255 new Attribute Type values, of format "TYPE.TLV.1" through "TYPE.TLV.255". The value zero "VALUE.0" is not used. Values 254-255 are marked "Reserved". All other values are "Unassigned". Value 26 has no special meaning.

For example, if a new attribute "Example-TLV" of data type "tlv" is assigned the identifier "245.1", then the extended tree will be allocated as below:

- * 245.1 Example-TLV
- * 245.1.{1-253} Unassigned
- * 245.1.{254-255} Reserved

Note that this example does not define an "Example-TLV" attribute.

The Attribute Type Tree can be extended multiple levels in one specification when the specification requests allocation of nested TLVs, as discussed below.

10.3.6. Allocation within a TLV

Specifications can request allocation of Attribute Type values within an Attribute of Data Type TLV. The encapsulating TLV can be allocated in the same specification, or it can have been previously allocated.

Specifications need to request allocation within a specific Attribute Type value (e.g. "TYPE.TLV.*"). Allocations are performed from the smallest Unassigned value, proceeding to the largest Unassigned value.

Where the Attribute being allocated is of Data Type TLV, the Attribute Type tree is extended by one level, as given in the previous section. Allocations can then be made within that level.

10.3.7. Allocation of Other Data Types

Attribute Type value allocations are otherwise allocated from the smallest Unassigned value, proceeding to the largest Unassigned value. e.g. Starting from 241.1, proceeding through 241.255, then to 242.1, through 242.255, etc.

11. Security Considerations

This document defines new formats for data carried inside of RADIUS, but otherwise makes no changes to the security of the RADIUS protocol.

Attacks on cryptographic hashes are well known, and are getting better with time, as discussed in[RFC4270]. RADIUS uses the MD5 hash [[RFC1321](#)] for packet authentication and attribute obfuscation. There are ongoing efforts in the IETF to analyze and address these issues for the RADIUS protocol.

As with any protocol change, code changes are required in order to implement the new features. These code changes have the potential to introduce new vulnerabilities in the software. Since the RADIUS server performs network authentication, it is an inviting target for attackers. We RECOMMEND that access to RADIUS servers be kept to a minimum.

12. References

12.1. Normative references

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12.2. Informative references

- [RFC1321] Rivest, R. "The MD5 Message-Digest Algorithm", [RFC 1321](#), April, 1992
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- [RFC2868] Zorn, G., et al, " RADIUS Attributes for Tunnel Protocol Support", [RFC 2868](#), June 2000.
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- [EDUROAM] Internal Eduroam testing page, data retrieved 04 August 2010.
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Acknowledgments

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Appendix A - Extended Attribute Generator Program

This section contains "C" program source which can be used for testing. It reads a line-oriented text file, parses it to create RADIUS formatted attributes, and prints the hex version of those attributes to standard output.

The input accepts a grammar similar to that given in [Section 8](#), with some modifications for usability. For example, blank lines are allowed, lines beginning with a '#' character are interpreted as comments, numbers (RADIUS Types, etc.) are checked for minimum / maximum values, and RADIUS Attribute lengths are enforced.

The program is included here for demonstration purposes only, and does not define a standard of any kind.

```
-----  
/*  
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 * authors of the code. All rights reserved.  
 *  
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 * EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED  
 * TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE,  
 * DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON  
 * ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY,
```



```
* OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT
* OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF
* SUCH DAMAGE.
*
* Author: Alan DeKok <aland@networkradius.com>
*/
#include <stdlib.h>
#include <stdio.h>
#include <stdint.h>
#include <string.h>
#include <errno.h>
#include <ctype.h>

static int encode_tlv(char *buffer, uint8_t *output, size_t outlen);

static const char *hextab = "0123456789abcdef";

static int encode_data_string(char *buffer,
                             uint8_t *output, size_t outlen)
{
    int length = 0;
    char *p;

    p = buffer + 1;

    while (*p && (outlen > 0)) {
        if (*p == '"') {
            return length;
        }

        if (*p != '\\') {
            *(output++) = *(p++);
            outlen--;
            length++;
            continue;
        }

        switch (p[1]) {
        default:
            *(output++) = p[1];
            break;

        case 'n':
            *(output++) = '\n';
            break;

        case 'r':
            *(output++) = '\r';
```



```
        break;

    case 't':
        *(output++) = '\t';
        break;
    }

    outlen--;
    length++;
}

fprintf(stderr, "String is not terminated\n");
return 0;
}

static int encode_data_tlv(char *buffer, char **endptr,
                          uint8_t *output, size_t outlen)
{
    int depth = 0;
    int length;
    char *p;

    for (p = buffer; *p != '\0'; p++) {
        if (*p == '{') depth++;
        if (*p == '}') {
            depth--;
            if (depth == 0) break;
        }
    }

    if (*p != '}') {
        fprintf(stderr, "No trailing '}' in string starting "
                "with \"%s\"\n",
                buffer);
        return 0;
    }

    *endptr = p + 1;
    *p = '\0';

    p = buffer + 1;
    while (isspace((int) *p)) p++;

    length = encode_tlv(p, output, outlen);
    if (length == 0) return 0;

    return length;
}
```



```
static int encode_data(char *p, uint8_t *output, size_t outlen)
{
    int length;

    if (!isspace((int) *p)) {
        fprintf(stderr, "Invalid character following attribute "
            "definition\n");
        return 0;
    }

    while (isspace((int) *p)) p++;

    if (*p == '{') {
        int sublen;
        char *q;

        length = 0;

        do {
            while (isspace((int) *p)) p++;
            if (!*p) {
                if (length == 0) {
                    fprintf(stderr, "No data\n");
                    return 0;
                }
                break;
            }
            sublen = encode_data_tlv(p, &q, output, outlen);
            if (sublen == 0) return 0;

            length += sublen;
            output += sublen;
            outlen -= sublen;
            p = q;
        } while (*q);

        return length;
    }

    if (*p == '"') {
        length = encode_data_string(p, output, outlen);
        return length;
    }

    length = 0;
    while (*p) {
```



```
    char *c1, *c2;

    while (isspace((int) *p)) p++;

    if (!*p) break;

    if(!(c1 = memchr(hextab, tolower((int) p[0]), 16)) ||
        !(c2 = memchr(hextab, tolower((int) p[1]), 16))) {
        fprintf(stderr, "Invalid data starting at "
            "\'%s\'\\n", p);
        return 0;
    }

    *output = ((c1 - hextab) << 4) + (c2 - hextab);
    output++;
    length++;
    p += 2;

    outlen--;
    if (outlen == 0) {
        fprintf(stderr, "Too much data\\n");
        return 0;
    }
}

if (length == 0) {
    fprintf(stderr, "Empty string\\n");
    return 0;
}

return length;
}

static int decode_attr(char *buffer, char **endptr)
{
    long attr;

    attr = strtol(buffer, endptr, 10);
    if (*endptr == buffer) {
        fprintf(stderr, "No valid number found in string "
            "starting with \''s\'\\n", buffer);
        return 0;
    }

    if (**endptr) {
        fprintf(stderr, "Nothing follows attribute number\\n");
        return 0;
    }
}
```



```
    if ((attr <= 0) || (attr > 256)) {
        fprintf(stderr, "Attribute number is out of valid "
            "range\n");
        return 0;
    }

    return (int) attr;
}

static int decode_vendor(char *buffer, char **endptr)
{
    long vendor;

    if (*buffer != '.') {
        fprintf(stderr, "Invalid separator before vendor id\n");
        return 0;
    }

    vendor = strtol(buffer + 1, endptr, 10);
    if (*endptr == (buffer + 1)) {
        fprintf(stderr, "No valid vendor number found\n");
        return 0;
    }

    if (!**endptr) {
        fprintf(stderr, "Nothing follows vendor number\n");
        return 0;
    }

    if ((vendor <= 0) || (vendor > (1 << 24))) {
        fprintf(stderr, "Vendor number is out of valid range\n");
        return 0;
    }

    if (**endptr != '.') {
        fprintf(stderr, "Invalid data following vendor number\n");
        return 0;
    }
    (*endptr)++;

    return (int) vendor;
}

static int encode_tlv(char *buffer, uint8_t *output, size_t outlen)
{
    int attr;
    int length;
    char *p;
```



```
    attr = decode_attr(buffer, &p);
    if (attr == 0) return 0;

    output[0] = attr;
    output[1] = 2;

    if (*p == '.') {
        p++;
        length = encode_tlv(p, output + 2, outlen - 2);
    } else {
        length = encode_data(p, output + 2, outlen - 2);
    }

    if (length == 0) return 0;
    if (length > (255 - 2)) {
        fprintf(stderr, "TLV data is too long\n");
        return 0;
    }

    output[1] += length;

    return length + 2;
}

static int encode_vsa(char *buffer, uint8_t *output, size_t outlen)
{
    int vendor;
    int attr;
    int length;
    char *p;

    vendor = decode_vendor(buffer, &p);
    if (vendor == 0) return 0;

    output[0] = 0;
    output[1] = (vendor >> 16) & 0xff;
    output[2] = (vendor >> 8) & 0xff;
    output[3] = vendor & 0xff;

    length = encode_tlv(p, output + 4, outlen - 4);
    if (length == 0) return 0;
    if (length > (255 - 6)) {
        fprintf(stderr, "VSA data is too long\n");
        return 0;
    }
}
```



```
        return length + 4;
    }

static int encode_evs(char *buffer, uint8_t *output, size_t outlen)
{
    int vendor;
    int attr;
    int length;
    char *p;

    vendor = decode_vendor(buffer, &p);
    if (vendor == 0) return 0;

    attr = decode_attr(p, &p);
    if (attr == 0) return 0;

    output[0] = 0;
    output[1] = (vendor >> 16) & 0xff;
    output[2] = (vendor >> 8) & 0xff;
    output[3] = vendor & 0xff;
    output[4] = attr;

    length = encode_data(p, output + 5, outlen - 5);
    if (length == 0) return 0;

    return length + 5;
}

static int encode_extended(char *buffer,
                           uint8_t *output, size_t outlen)
{
    int attr;
    int length;
    char *p;

    attr = decode_attr(buffer, &p);
    if (attr == 0) return 0;

    output[0] = attr;

    if (attr == 26) {
        length = encode_evs(p, output + 1, outlen - 1);
    } else {
        length = encode_data(p, output + 1, outlen - 1);
    }
    if (length == 0) return 0;
    if (length > (255 - 3)) {
        fprintf(stderr, "Extended Attr data is too long\n");
    }
}
```



```
        return 0;
    }

    return length + 1;
}

static int encode_extended_flags(char *buffer,
                                uint8_t *output, size_t outlen)
{
    int attr;
    int length, total;
    char *p;

    attr = decode_attr(buffer, &p);
    if (attr == 0) return 0;

    /* output[0] is the extended attribute */
    output[1] = 4;
    output[2] = attr;
    output[3] = 0;

    if (attr == 26) {
        length = encode_evs(p, output + 4, outlen - 4);
        if (length == 0) return 0;

        output[1] += 5;
        length -= 5;
    } else {
        length = encode_data(p, output + 4, outlen - 4);
    }
    if (length == 0) return 0;

    total = 0;
    while (1) {
        int sublen = 255 - output[1];

        if (length <= sublen) {
            output[1] += length;
            total += output[1];
            break;
        }

        length -= sublen;

        memmove(output + 255 + 4, output + 255, length);
        memcpy(output + 255, output, 4);

        output[1] = 255;
    }
}
```



```
        output[3] |= 0x80;

        output += 255;
        output[1] = 4;
        total += 255;
    }

    return total;
}

static int encode_rfc(char *buffer, uint8_t *output, size_t outlen)
{
    int attr;
    int length, sublen;
    char *p;

    attr = decode_attr(buffer, &p);
    if (attr == 0) return 0;

    length = 2;
    output[0] = attr;
    output[1] = 2;

    if (attr == 26) {
        sublen = encode_vsa(p, output + 2, outlen - 2);
    } else if ((*p == ' ') || ((attr < 241) || (attr > 246))) {
        sublen = encode_data(p, output + 2, outlen - 2);
    } else {
        if (*p != '.') {
            fprintf(stderr, "Invalid data following "
                "attribute number\n");
            return 0;
        }

        if (attr < 245) {
            sublen = encode_extended(p + 1,
                output + 2, outlen - 2);
        } else {
            /*
             *   Not like the others!
             */
            return encode_extended_flags(p + 1, output, outlen);
        }
    }

    if (sublen == 0) return 0;
}
```



```
    if (sublen > (255 - 2)) {
        fprintf(stderr, "RFC Data is too long\n");
        return 0;
    }

    output[1] += sublen;
    return length + sublen;
}

int main(int argc, char *argv[])
{
    int lineno;
    size_t i, outlen;
    FILE *fp;
    char input[8192], buffer[8192];
    uint8_t output[4096];

    if ((argc < 2) || (strcmp(argv[1], "-") == 0)) {
        fp = stdin;
    } else {
        fp = fopen(argv[1], "r");
        if (!fp) {
            fprintf(stderr, "Error opening %s: %s\n",
                argv[1], strerror(errno));
            exit(1);
        }
    }

    lineno = 0;
    while (fgets(buffer, sizeof(buffer), fp) != NULL) {
        char *p = strchr(buffer, '\n');

        lineno++;

        if (!p) {
            if (!feof(fp)) {
                fprintf(stderr, "Line %d too long in %s\n",
                    lineno, argv[1]);
                exit(1);
            }
        } else {
            *p = '\0';
        }

        p = strchr(buffer, '#');
        if (p) *p = '\0';

        p = buffer;
```



```
while (isspace((int) *p)) p++;
if (!*p) continue;

strcpy(input, p);
outlen = encode_rfc(input, output, sizeof(output));
if (outlen == 0) {
    fprintf(stderr, "Parse error in line %d of %s\n",
            lineno, input);
    exit(1);
}

printf("%s -> ", buffer);
for (i = 0; i < outlen; i++) {
    printf("%02x ", output[i]);
}
printf("\n");
}

if (fp != stdin) fclose(fp);

return 0;
}
```

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