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RFC 9542
IANA Considerations and IETF Protocol and Documentation Usage for IEEE 802 Parameters

Abstract

Some IETF protocols make use of Ethernet frame formats and IEEE 802 parameters. This document discusses several aspects of such parameters and their use in IETF protocols, specifies IANA considerations for assignment of points under the IANA Organizationally Unique Identifier (OUI), and provides some values for use in documentation. This document obsoletes RFC 7042.

Status of This Memo

This memo documents an Internet Best Current Practice.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on BCPs is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc9542.

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1. Introduction

Some IETF protocols use Ethernet or other IEEE 802-related communication frame formats and parameters [IEEE802]. These include Media Access Control (MAC) addresses and protocol identifiers. The IEEE Registration Authority [IEEE_RA] manages the assignment of identifiers used in IEEE 802 networks, in some cases assigning blocks of such identifiers whose sub-assignment is managed by the entity to which the block is assigned. The IEEE RA also provides a number of tutorials concerning these parameters [IEEEtutorials].

IANA has been assigned an Organizationally Unique Identifier (OUI) by the IEEE RA and an associated set of MAC addresses and other organizationally unique code points based on that OUI. This document specifies IANA considerations for the assignment of code points under that IANA OUI, including MAC addresses and protocol identifiers, and provides some values for use in documentation. As noted in [RFC2606] and [RFC5737], the use of designated code values reserved for documentation and examples reduces the likelihood of conflicts and confusion arising from such code points conflicting with code points assigned for some deployed use. This document also discusses several other uses by the IETF of IEEE 802 code points, including IEEE 802 Connectivity Fault Management (CFM) code points [RFC7319] and IEEE 802 Link Local Discovery Protocol (LLDP) [IEEE802.1AB] Vendor-Specific TLV Sub-Types [RFC8520]. It also specifies Concise Binary Object Representation (CBOR) tags for MAC addresses and OUIs / Company Identifiers (CIDs).

Descriptions herein of [IANA] policies and procedures are authoritative, but descriptions of IEEE registration policies, procedures, and standards are only informative; for authoritative IEEE information, consult the IEEE sources.

[RFC8126] is incorporated herein except where there are contrary provisions in this document. In this document, "IESG Ratification", specified in Section 5.1, refers to a combination of Expert Review and IESG Approval as those are defined in [RFC8126], where IESG Approval is required only if the Expert does not reject the request. It is NOT the same as just "IESG Approval" in [RFC8126].

1.1. Notations Used in This Document

This document uses hexadecimal notation. Each octet (that is, 8-bit byte) is represented by two hexadecimal digits giving the value of the octet as an unsigned integer. Successive octets are separated by a hyphen. This document consistently uses IETF ("network") bit ordering; although, the physical order of bit transmission within an octet on an IEEE [IEEE.802.3_2012] link is from the lowest order bit to the highest order bit (i.e., the reverse of the IETF's ordering).

In this document:

"AFN" Address Family Number [RFC4760].

"CBOR" Concise Binary Object Representation [RFC8949].

"CFM"	Connectivity Fault Management [RFC7319].
"CID"	Company Identifier. See Section 2.1.2.
"DSAP"	Destination Service Access Point. See Section 3.
"EUI"	Extended Unique Identifier.
"EUI-48"	48-bit EUI
"IEEE"	Institute of Electrical and Electronics Engineers [IEEE].
"IEEE 802"	The LAN/MAN Standards Committee [IEEE802].
"IEEE RA"	IEEE Registration Authority [IEEE_RA].
"IEEE SA"	IEEE Standards Association [IEEE_SA].
"LLC"	Logical Link Control. The type of frame header where the protocol is identified by source and destination LSAP fields. See Section 3.
"LSAP"	Link-Layer Service Access Point. See Section 3.
"MA-L"	MAC Address Block Large.
"MA-M"	MAC Address Block Medium.
"MA-S"	MAC Address Block Small.
"MAC"	Media Access Control, not Message Authentication Code.
"MAC-48"	A 48-bit MAC address. This term is obsolete. If globally unique, use EUI-48.
"OUI"	Organizationally Unique Identifier. See Section 2.1.2.
"RRTYPE"	A DNS Resource Record type [RFC6895].
"SLAP"	IEEE 802 Structured Local Address Plan [IEEE802_OandA]. See Section 2.1.1.
"SNAP"	Subnetwork Access Protocol. See Section 3.
"SSAP"	Source Service Access Point. See Section 3.
"tag"	"Tag" is used in two contexts in this document. For "Ethernet tag", see Section 3. For "CBOR tag", see Section 2.4.
"TLV"	Type-Length-Value.
"**"	The double asterisk symbol indicates exponentiation. For example, 2**24 is two to the twenty-fourth power.

1.2. The IEEE Registration Authority

Originally the responsibility of the Xerox Corporation, the registration authority for Ethernet parameters since 1986 has been the IEEE Registration Authority, available on the Web at [IEEE_RA].

The IEEE Registration Authority operates under the direction of the IEEE Standards Association (IEEE SA) Board of Governors, with oversight by the IEEE Registration Authority Committee (IEEE RAC). The IEEE RAC is a committee of the Board of Governors.

Anyone may apply to that authority for parameter assignments. The IEEE Registration Authority may impose fees or other requirements but commonly waives fees for applications from standards development organizations. Lists of assignments and their holders are downloadable from the IEEE Registration Authority site.

1.3. The IANA Organizationally Unique Identifier

The Organizationally Unique Identifier (OUI) 00-00-5E has been assigned to IANA by the IEEE Registration Authority.

There is no OUI value reserved at this time for documentation, but there are documentation code points under the IANA OUI specified below.

1.4. CFM Code Points

IEEE Std 802.1Q [IEEE.802.1Q_2014] allocates two blocks of 802 Connectivity Fault Management (CFM) code points to the IETF, one for CFM OpCodes and one for CFM TLV Types. For further information, see [RFC7319]. The IANA "Connectivity Fault Management (CFM) OAM IETF Parameters" registry has subregistries for these code points. This document does not further discuss these blocks of code points.

2. Ethernet Identifier Parameters

This section includes information summarized from [IEEE802_OandA] that is being provided for context. The definitive information, which prevails in case of any discrepancy, is in [IEEE802_OandA].

Section 2.1 discusses 48-bit MAC identifiers, their relationship to OUIs and other prefixes, and assignment under the IANA OUI. Section 2.2 extends this to 64-bit identifiers. Section 2.3 discusses other IETF MAC identifier uses not under the IANA OUI. Section 2.4 specifies CBOR tags for MAC addresses and OUIs/CIDs.

> Historical Note: [RAC_OUI] is an expired Internet-Draft that provides additional historic information on [IEEE802] registries.

2.1. 48-Bit MAC Identifiers, OUIs, and Other Prefixes

48-bit MAC "addresses" are the most commonly used Ethernet interface identifiers. Those that are globally unique are also called EUI-48 identifiers (Extended Unique Identifier 48). An EUI-48 is structured into an initial prefix assigned by the IEEE Registration Authority and additional bits assigned by the prefix owner. As of 2023, there are three lengths of prefixes assigned, as shown in the table below; however, some prefix bits can have special meaning, as shown in Figure 1.

Prefix Length in Bits	Name	Owner Supplied Bits for 48-bit MAC Addresses
24	MA-L	24
28	MA-M	20
36	MA-S	12

Table 1

The bottom (least significant) four bits of the first octet of the 6-octet 48-bit MAC have special meaning, as shown in Figure 1, and are referred to below as the M, X, Y, and Z bits.

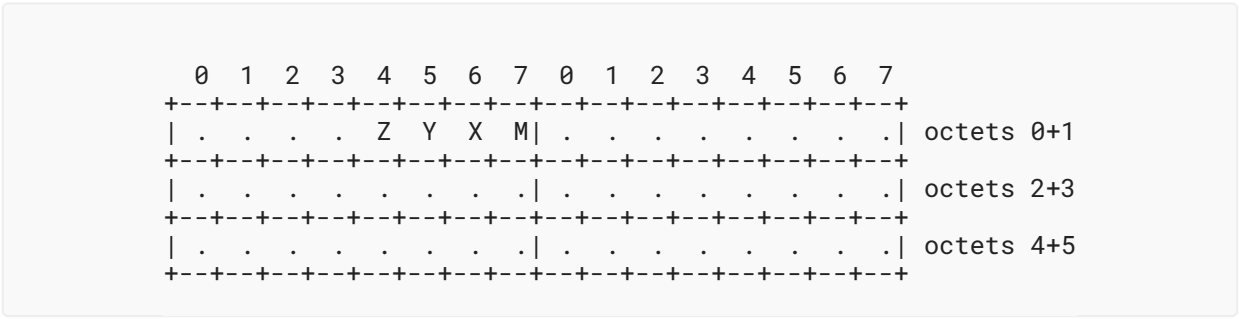

Figure 1: 48-bit MAC Address Structure

For global addresses, X = 0 and a MAC address begins with 3 octets or a larger initial prefix indicating the assignee of the block of MAC addresses. This prefix is followed by a sequence of additional octets so as to add up to the total MAC address length. For example, the IEEE assigns MAC Address Block Small (MA-S), where the first four and a half octets (36 bits) are assigned, giving the holder of the MA-S one and a half octets (12 bits) they can control in constructing 48-bit MAC addresses; other prefix lengths are also available [IEEEtutorials].

An AFN, a DNS RRTYPE, and a CBOR tag have been assigned for 48-bit MAC addresses, as discussed in Sections 2.4, 5.3, and 5.9.

IEEE Std 802 describes assignment procedures and policies for IEEE 802-related identifiers [IEEE802_OandA]. IEEE RA documentation on EUIs, OUIs, and CIDs is available at [IEEEtutorials].

2.1.1. Special First Octet Bits

There are bits within the initial octet of an IEEE MAC address that have special significance [IEEE802_OandA], as described as follows:

M bit - This bit is frequently referred to as the "group" or "multicast" bit. If it is zero, the MAC address is unicast. If it is a one, the address is groupcast (multicast or broadcast). This meaning is independent of the values of the X, Y, and Z bits.

X bit - This bit is also called the "universal/local" bit. If it is zero, the MAC address is a global address under the control of the owner of the IEEE-assigned prefix. Previously, if it was a one, the MAC address was considered "local" and under the assignment and control of the local network operator (but see Section 2.3). If it is a one and if the IEEE 802 Structured Local Address Plan (SLAP) is in effect, the nature of the MAC address is optionally determined by the Y and Z bits, as described below.

Y+Z bits - These two bits have no special meaning if the X bit is zero. If the X bit is one and if the IEEE 802 Structured Local Address Plan (SLAP) is in effect, these two bits divide the formerly uniform "local" MAC address space into four quadrants as follows and is further described below:

Y bit	Z bit	Quadrant
0	0	Administratively Assigned
0	1	Extended Local
1	0	Reserved
1	1	Standard Assigned

Table 2

While a local network administrator can assign any addresses with the X bit a one, the optional SLAP characterizes the four quadrants of the "local" address space using the Y and Z bits as follows:

Administratively Assigned - MAC addresses in this quadrant are called Administratively Assigned Identifiers. This is intended for arbitrary local assignment, such as random assignment; however, see Section 2.3.1.

Extended Local - MAC addresses in this quadrant are called Extended Local Identifiers. These addresses are not actually "local" under SLAP. They are available to the organization that has been assigned the CID (see Section 2.1.2) specifying the other 20 bits of the 24-bit prefix with X, Y, and Z bits having the values 1, 0, and 1, respectively.

Reserved - MAC addresses in this quadrant are reserved for future use under the SLAP. Until such future use, they could be locally assigned as Administratively Assigned Identifiers are assigned, but there is a danger that future SLAP use would conflict with such local assignments.

Standard Assigned - MAC addresses in this quadrant are called Standard Assigned Identifiers (SAIs). An SAI is assigned by a protocol specified in an IEEE 802 standard, for example, [IEEE802.1CQ] (but see NOTE below).

NOTE: While the SLAP has MAC addresses assigned through a local protocol in the SAI quadrant and assigned by a protocol specified in an IEEE 802 standard, the SLAP is optional. Local network administrators may use the IETF protocol provisions in [RFC8947] and [RFC8948], which support assignment of a MAC address in the local MAC address space using DHCPv6 [RFC8415] or other protocol methods.

NOTE: There isn't any automated way to determine if or to what extent a local network is configured for and/or operating according to SLAP.

2.1.2. OUIs and CIDs

MA-L, MA-M, and MA-S MAC prefixes are assigned with the Local bit zero. The assignee of an OUI is exclusively authorized to assign group MAC addresses by extending a modified version of the assigned OUI in which the M bit (see Figure 1) is set to 1 [IEEEtutorials].

The Local bit is zero for globally unique EUI-48 identifiers assigned by the owner of a MAC-L or owner of a longer prefix. If the Local bit is a one, the identifier has historically been a local identifier under the control of the local network administrator; however, there are now recommendations on optional management of the local address space, as discussed in Section 2.1.1. If the Local bit is a one, the holder of an OUI has no special authority over MAC identifiers whose first 3 octets correspond to their OUI or the beginning of their longer prefix.

A CID is a 24-bit Company Identifier. It is assigned for organizations that need such an identifier that can be used in place of an OUI but do not need to assign subsidiary global MAC addresses. A CID has X and Z bits equal to 1 and its Y bit equal to 0 (see Figure 1).

An AFN and a CBOR tag have been assigned for OUIs/CIDs, as discussed in Sections 2.4, 5.3, and 5.9.

2.1.3. 48-Bit MAC Assignments under the IANA OUI

The OUI 00-00-5E has been assigned to IANA, as stated in Section 1.3 above. This includes 2**24 48-bit multicast identifiers from 01-00-5E-00-00-00 to 01-00-5E-FF-FF-FF and 2**24 EUI-48 unicast identifiers from 00-00-5E-00-00-00 to 00-00-5E-FF-FF-FF.

Of these identifiers, the sub-blocks reserved or thus far assigned are as follows:

Unicast, all blocks of 2**8 addresses thus far:

00-00-5E-00-00-00 through 00-00-5E-00-00-FF: reserved and require IESG Ratification for assignment (see Section 5.1).

00-00-5E-00-01-00 through 00-00-5E-00-01-FF: assigned for the Virtual Router Redundancy Protocol (VRRP) [RFC5798].

00-00-5E-00-02-00 through 00-00-5E-00-02-FF: assigned for the IPv6 Virtual Router Redundancy Protocol (IPv6 VRRP) [RFC5798].

00-00-5E-00-52-00 through 00-00-5E-00-52-FF: used for very small assignments. As of 2023, 4 out of these 256 values have been assigned. See [EthernetNum].

00-00-5E-00-53-00 through 00-00-5E-00-53-FF: assigned for use in documentation by this document.

00-00-5E-90-01-00 through 00-00-5E-90-01-FF: used for very small assignments that need parallel unicast and multicast MAC addresses. As of 2023, 1 out of these 256 values has been assigned. See [EthernetNum].

Multicast:

01-00-5E-00-00-00 through 01-00-5E-7F-FF-FF: 2**23 addresses assigned for IPv4 multicast [RFC1112].

01-00-5E-80-00-00 through 01-00-5E-8F-FF-FF: 2**20 addresses assigned for MPLS multicast [RFC5332].

01-00-5E-90-00-00 through 01-00-5E-90-00-FF: 2**8 addresses being used for very small assignments. As of 2023, 4 out of these 256 values have been assigned. See [EthernetNum].

01-00-5E-90-01-00 through 01-00-5E-90-01-FF: used for very small assignments that need parallel unicast and multicast MAC addresses. As of 2023, 1 out of these 256 values has been assigned. See [EthernetNum].

01-00-5E-90-10-00 through 01-00-5E-90-10-FF: 2**8 addresses assigned for use in documentation by this document.

For more detailed and up-to-date information, see the "IANA OUI Ethernet Numbers" registry at [EthernetNum].

2.1.4. 48-Bit MAC Documentation Values

The following values have been assigned for use in documentation:

- 00-00-5E-00-53-00 through 00-00-5E-00-53-FF for unicast and
- 01-00-5E-90-10-00 through 01-00-5E-90-10-FF for multicast.

2.1.5. 48-Bit IANA MAC Assignment Considerations

48-bit assignments under the current or a future IANA OUI (see Section 5.6) must meet the following requirements:

- must be for standards purposes (either for an IETF Standard or other standard related to IETF work),

- must be for a power-of-two-sized block of identifiers starting at a boundary that is an equal or greater power of two, including the assignment of one (2**0) identifier,
- must not be used to evade the requirement for network interface vendors to obtain their own block of identifiers from the IEEE, and
- must be documented in an Internet-Draft or RFC.

In addition, approval must be obtained as follows (see the procedure in Section 5.1):

- Small to medium assignments of a block of 1, 2, 4, ..., 32768, 65536 (2**0, 2**1, 2**2, ..., 2**15, 2**16) EUI-48 identifiers require Expert Review (see Section 5.1).
- Large assignments of 131072 (2**17) or more EUI-48 identifiers require IESG Ratification (see Section 5.1).

2.2. 64-Bit MAC Identifiers

IEEE also defines a system of 64-bit MAC identifiers, including EUI-64s. EUI-64 identifiers are used as follows:

- In IEEE Std 1394 [IEEE1394] (also known as FireWire and i.Link)
- In IEEE Std 802.15.4 [IEEE802.15.4] (also known as Zigbee)
- In [InfiniBand]
- In a modified form to construct some IPv6 Interface Identifiers, as described in Section 2.2.1; although, this use is now deprecated

Adding a 5-octet (40-bit) extension to a 3-octet (24-bit) assignment, or a shorter extension to longer assigned prefixes [RAC_OUI] so as to total 64 bits, produces an EUI-64 identifier under that OUI or longer prefix. As with EUI-48 identifiers, the first octet has the same special low-order bits.

An AFN, a DNS RRTYPE, and CBOR tags have been assigned for 64-bit MAC addresses, as discussed in Sections 2.4, 5.3, and 5.9.

The discussion below is almost entirely in terms of the "Modified" form of EUI-64 identifiers; however, anyone assigned such an identifier can also use the unmodified form as a MAC identifier on any link that uses such 64-bit identifiers for interfaces.

2.2.1. IPv6 Use of Modified EUI-64 Identifiers

The approach described below for constructing IPv6 Interface Identifiers is now deprecated, and the method specified in [RFC8064] is recommended.

EUI-64 identifiers have been used to form the lower 64 bits of some IPv6 addresses (Section 2.5.1 and Appendix A of [RFC4291] and Appendix A of [RFC5214]). When so used, the EUI-64 is modified by inverting the X (Local/Global) bit to form an IETF "Modified EUI-64 identifier". Below is an illustration of a Modified EUI-64 unicast identifier under the IANA OUI, where aa-bb-cc-dd-ee is the extension.

```
02-00-5E-aa-bb-cc-dd-ee
```

The first octet is shown as 02 rather than 00 because, in Modified EUI-64 identifiers, the sense of the X bit is inverted compared with EUI-48 identifiers. It is the globally unique values (universal scope) that have the 0x02 bit (also known as the X or universal/local bit) on in the first octet, while those with this bit off are typically locally assigned and out of scope for global assignment.

The X (Local/Global) bit was inverted to make it easier for network operators to type in local-scope identifiers. Thus, such Modified EUI-64 identifiers as 1, 2, etc. (ignoring leading zeros) are local. Without the modification, they would have to be 02-00-00-00-00-00-00-01, 02-00-00-00-00-00-00-02, etc. to be local.

As with 48-bit MAC identifiers, the M bit (0x01) on in the first octet indicates a group identifier (multicast or broadcast).

When the first two octets of the extension of a Modified EUI-64 identifier are FF-FE, the remainder of the extension is a 24-bit value, as assigned by the OUI owner for an EUI-48. For example:

02-00-5E-FF-FE-yy-yy-yy

or

03-00-5E-FF-FE-yy-yy-yy

where yy-yy-yy is the portion (of an EUI-48 global unicast or multicast identifier) that is assigned by the OUI owner (IANA in this case). Thus, any holder of one or more EUI-48 identifiers under the IANA OUI also has an equal number of Modified EUI-64 identifiers that can be formed by inserting FF-FE in the middle of their EUI-48 identifiers and inverting the Local/Global bit.

In addition, certain Modified EUI-64 identifiers under the IANA OUI are reserved for holders of IPv4 addresses as follows:

02-00-5E-FE-xx-xx-xx-xx

where xx-xx-xx-xx is a 32-bit IPv4 address. The owner of an IPv4 address has both a unicast- and multicast-derived EUI-64 address. Modified EUI-64 identifiers from

02-00-5E-FE-F0-00-00-00 to 02-00-5E-FE-FF-FF-FF-FF

are effectively reserved pending the specification of IPv4 "Class E" addresses [RFC1112]. However, for Modified EUI-64 identifiers based on an IPv4 address, the Local/Global bit should be set to correspond to whether the IPv4 address is local or global. (Keep in mind that the sense of the Modified EUI-64 identifier Local/Global bit is reversed from that in (unmodified) EUI-64 identifiers.)

2.2.2. EUI-64 IANA Assignment Considerations

The following table shows which Modified EUI-64 identifiers under the IANA OUI are reserved, assigned, or available as indicated. As noted above, the corresponding MAC addresses can be determined by complementing the 02 bit in the first octet. In all cases, the corresponding multicast 64-bit MAC addresses formed by complementing the 01 bit in the first octet have the same status as the modified 64-bit unicast address blocks listed below.

Addresses	Usage	Reference
00-00-00-00-00 to 0F-FF-FF-FF-FF	Reserved	RFC 9542
10-00-00-00-00 to 10-00-00-00-FF	Documentation	RFC 9542
10-00-00-01-00 to FC-FF-FF-FF-FF	Unassigned	
FD-00-00-00-00 to FD-FF-FF-FF-FF	Reserved	RFC 9542
FE-00-00-00-00 to FE-FF-FF-FF-FF	IPv4 Addr Holders	RFC 9542
FF-00-00-00-00 to FF-FD-FF-FF-FF	Reserved	RFC 9542
FF-FE-00-00-00 to FF-FE-FF-FF-FF	IANA EUI-48 Holders	RFC 9542
FF-FF-00-00-00 to FF-FF-FF-FF-FF	Reserved	RFC 9542

Table 3: IANA 64-bit MAC Addresses

The reserved identifiers above require IESG Ratification (see Section 5.1) for assignment. IANA EUI-64 identifier assignments under the IANA OUI must meet the following requirements:

- must be for standards purposes (either for an IETF Standard or other standard related to IETF work),
- must be for a power-of-two-sized block of identifiers starting at a boundary that is an equal or greater power of two, including the assignment of one (2**0) identifier,
- must not be used to evade the requirement for network interface vendors to obtain their own block of identifiers from the IEEE, and
- must be documented in an Internet-Draft or RFC.

In addition, approval must be obtained as follows (see the procedure in Section 5.1):

- Small to medium assignments of a block of 1, 2, 4, ..., 134217728, 268435456 (2**0, 2**1, 2**2, ..., 2**27, 2**28) EUI-64 identifiers require Expert Review (see Section 5.1).
- Large assignments of 536870912 (2**29) or more EUI-64 identifiers require IESG Ratification (see Section 5.1).

2.2.3. EUI-64 Documentation Values

The following blocks of unmodified 64-bit MAC addresses are for documentation use. The IPv4-derived addresses are based on the IPv4 documentation addresses [RFC5737], and the MAC-derived addresses are based on the EUI-48 documentation addresses above.

Unicast values for documentation use:

00-00-5E-EF-10-00-00-00 to 00-00-5E-EF-10-00-00-FF general

00-00-5E-FE-C0-00-02-00 to 00-00-5E-FE-C0-00-02-FF and 00-00-5E-FE-C6-33-64-00 to 00-00-5E-FE-C6-33-64-FF and 00-00-5E-FE-CB-00-71-00 to 00-00-5E-FE-CB-00-71-FF IPv4 derived

00-00-5E-FF-FE-00-53-00 to 00-00-5E-FF-FE-00-53-FF EUI-48 derived

00-00-5E-FE-EA-C0-00-02 and 00-00-5E-FE-EA-C6-33-64 and 00-00-5E-FE-EA-CB-00-71 IPv4 multicast derived from IPv4 unicast [RFC6034]

Multicast values for documentation use:

01-00-5E-EF-10-00-00-00 to 01-00-5E-EF-10-00-00-FF general

01-00-5E-FE-C0-00-02-00 to 01-00-5E-FE-C0-00-02-FF and 01-00-5E-FE-C6-33-64-00 to 01-00-5E-FE-C6-33-64-FF and 01-00-5E-FE-CB-00-71-00 to 01-00-5E-FE-CB-00-71-FF IPv4 derived

01-00-5E-FE-EA-C0-00-02 and 01-00-5E-FE-EA-C6-33-64 and 01-00-5E-FE-EA-CB-00-71 IPv4 multicast derived from IPv4 unicast [RFC6034]

01-00-5E-FF-FE-90-10-00 to 01-00-5E-FF-FE-90-10-FF EUI-48 derived

2.3. Other 48-bit MAC Identifiers Used by the IETF

There are two other blocks of 48-bit MAC identifiers that are used by the IETF as described below.

2.3.1. Identifiers with a '33-33' Prefix

All 48-bit multicast MAC identifiers prefixed with "33-33" (that is, the 2**32 multicast MAC identifiers in the range from 33-33-00-00-00-00 to 33-33-FF-FF-FF-FF) are used as specified in [RFC2464] for IPv6 multicast. In all of these identifiers, the Group bit (the bottom bit of the first octet) is on, as is required to work properly with existing hardware as a multicast identifier. They also have the Local bit on, but any Ethernet using standard IPv6 multicast should note that these addresses will be used for that purpose. These multicast MAC addresses fall into the Administratively Assigned SLAP quadrant (see Section 2.1.1).

Historical Notes: It was the custom during IPv6 design to use "3" for unknown or example values, and 3333 Coyote Hill Road, Palo Alto, California is the address of Palo Alto Research Center (PARC), formerly "Xerox PARC". Ethernet was originally specified by the Digital

Equipment Corporation, Intel Corporation, and Xerox Corporation. The pre-IEEE [IEEE.802.3_2012] Ethernet protocol has sometimes been known as "DIX" Ethernet from the first letters of the names of these companies.

2.3.2. The 'CF Series'

The Informational [RFC2153] declared the 3-octet values from CF-00-00 through CF-FF-FF to be "OUIs" available for assignment by IANA to software vendors for use in PPP [RFC1661] or for other uses where vendors do not otherwise need an IEEE-assigned OUI. When used as 48-bit MAC prefixes, these values have all of the Z, Y, X (Local) and M (Group) special bits at the bottom of the first octet equal to one, while all IEEE-assigned OUIs thus far have the X and M bits as zero and all CIDs have the Y and M bits as zero; thus, there can be no conflict between CF Series "OUIs" and IEEE-assigned OUIs/CIDs. Multicast MAC addresses constructed with a "CF" series OUI would fall into the Standard Assigned SLAP quadrant (see Section 2.1.1). The Group bit is meaningless in PPP. To quote [RFC2153]: "The 'CF0000' series was arbitrarily chosen to match the PPP NLPID 'CF', as a matter of mnemonic convenience." (For further information on Network Layer Protocol Identifiers (NLPIDs), see [RFC6328].)

CF-00-00 is reserved, and IANA lists multicast identifier CF-00-00-00-00-00 as used for Ethernet loopback tests.

In over a decade of availability, only a handful of values in the CF Series have been assigned. (See the "IANA OUI Ethernet Numbers" [EthernetNum] and "Point-to-Point (PPP) Protocol Field Assignments" [PPPNum] registry groups).

2.3.2.1. Changes to RFC 2153

The IANA considerations in [RFC2153] were updated as follows by the approval of [RFC5342] and remain as updated (no technical changes have been made):

- Use of these 'CF Series' identifiers based on IANA assignment was deprecated.
- IANA was instructed not to assign any further values in the 'CF Series'.

2.4. CBOR Tags

The Concise Binary Object Representation (CBOR) [RFC8949] is a data format whose design goals include the possibility of very small code size, fairly small message size, and extensibility. In CBOR, a data item can be enclosed by a CBOR tag to give it some additional semantics identified by that tag. CBOR-tagged data items (fields) are not used in actual IEEE 802 address fields but may be used in CBOR-encoded parts of protocol messages.

IANA has assigned 48 as the CBOR tag to indicate a MAC address. The enclosed data item is an octet string. The length of the octet string indicates whether a 48-bit (6 octet) or 64-bit (8 octet) MAC address is encoded. Should some other multiple of 8 bits length MAC addresses be used in the future, such as a 128-bit (16 octet) MAC address, the 48 tag will be used.

IANA has assigned 1048 as the CBOR tag to indicate an OUI, CID, or "CF" series organizational identifier. The enclosed data item is an octet string of length 3 to hold the 24-bit OUI or CID (see Section 2.1.2).

3. Ethernet Protocol Parameters

Ethernet protocol parameters provide a means of indicating, near the beginning of a frame, the contents of that frame -- for example, that it contains IPv4 or IPv6.

There are two types of protocol identifier parameters (see [EthernetNum]) that can occur in Ethernet frames:

EtherTypes:
: These are 16-bit identifiers that, when considered as an unsigned integer, are equal to or larger than 0x0600. Figure 2 shows the simplest case where the EtherType of the protocol data in the frame appears immediately after the destination and source MAC addresses. [IEEE802_OandA] specifies two EtherTypes for local, experimental use: 0x88B5 and 0x88B6.

LSAPs:
: These are 8-bit protocol identifiers that occur in pairs after a field that gives the frame length. Such a length must, when considered as an unsigned integer, be less than 0x5DD, or it could be mistaken as an EtherType. However, the LLC encapsulation EtherType 0x8870 [IEEE802.1AC] may also be used in place of such a length as a "length indication" of nonspecific length. LSAPs occur in pairs, where one is intended to indicate the source protocol handler (SSAP) and one is intended to indicate the destination protocol handler (DSAP); however, use cases where the two are different have been relatively rare. See Figure 3 for the simplest case where the length field appears immediately after the destination and source MAC addresses. In that figure, the CTL (control) field value of 3 indicates datagram service. This type of protocol identification is sometimes called "LLC" (Logical Link Control).

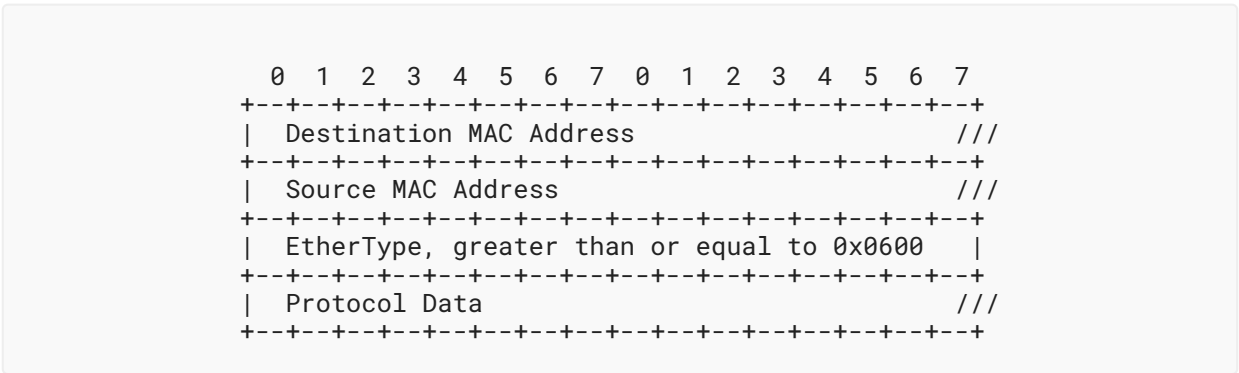

Figure 2: EtherType Frame Protocol Labeling

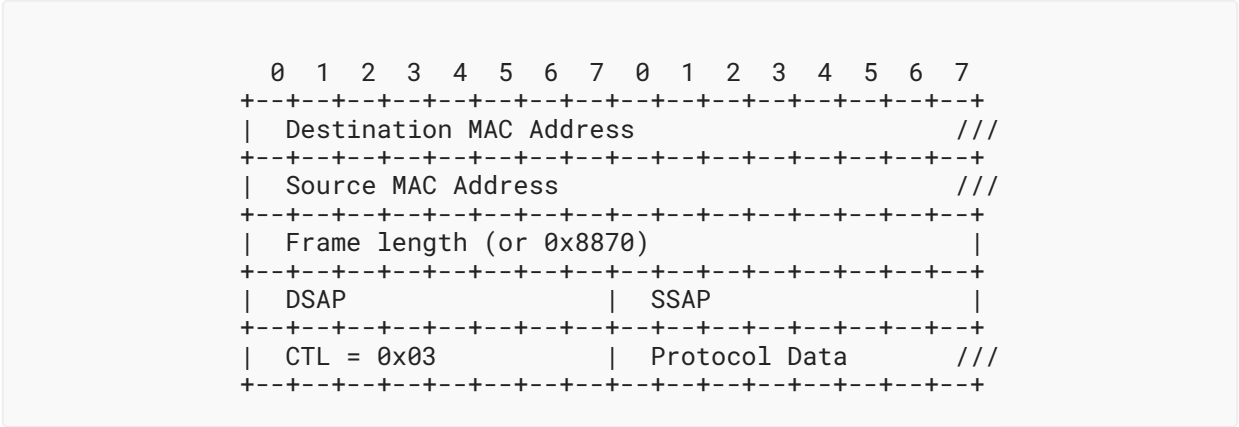

Figure 3: LSAP Frame Protocol Labeling

The concept of EtherType labeling has been extended to labeling by Ethernet "tags". An Ethernet tag in this sense is a prefix whose type is identified by an EtherType that is then followed by either another tag, an EtherType, or an LLC Link-Layer Service Access Point (LSAP) protocol indicator for the "main" body of the frame. Customarily, in the world of [IEEE802_OandA], tags are a fixed length and do not include any encoding of their own length. An example is the C-Tag (formerly the Q-Tag) [IEEE.802.1Q_2014]. It provides customer VLAN and priority information for a frame. Any device that is processing a frame cannot, in general, safely process anything in the frame past an EtherType it does not understand.

Neither EtherTypes nor LSAPs are assigned by IANA; they are assigned by the IEEE Registration Authority [IEEE_RA] (see Section 1.2 and Appendix B). However, both LSAPs and EtherTypes have extension mechanisms so that they can be used with five-octet Ethernet protocol identifiers under an OUI, including those assigned by IANA under the IANA OUI.

When using the IEEE 802 Logical Link Control (LLC) format (Subnetwork Access Protocol (SNAP)) [IEEE802_OandA] for a frame, an OUI-based protocol identifier can be expressed as follows:

xx-xx-AA-AA-03-yy-yy-yy-zz-zz

where xx-xx is the frame length and, as above, must be small enough not to be confused with an EtherType; "AA" is the LSAP that indicates this use and is sometimes referred to as the SNAP Service Access Point (SNAP SAP); "03" is the LLC control octet indicating datagram service; yy-yy-yy is an OUI; and zz-zz is a protocol number, under that OUI, assigned by the OUI owner. The five-octet length for such OUI-based protocol identifiers results, with the LLC control octet ("0x03"), in the preservation of 16-bit alignment.

When using an EtherType to indicate the main type for a frame body, the special "OUI Extended EtherType" 0x88B7 is available. Using this EtherType, a frame body can begin with

88-B7-yy-yy-yy-zz-zz

where yy-yy-yy and zz-zz have the same meaning as in the SNAP format described above; however, this format with EtherType 0x88B7 does not preserve 16-bit alignment.

It is also possible, within the SNAP format, to use an arbitrary EtherType. Putting the EtherType as the zz-zz field after an all-zeros OUI (00-00-00) does this. It looks like

xx-xx-AA-AA-03-00-00-00-zz-zz

where zz-zz is the EtherType.

As well as labeling frame contents, IEEE 802 protocol types appear within Non-Broadcast Multi-Access (NBMA) Next Hop Resolution Protocol [RFC2332] messages. Such messages have provisions for both two-octet EtherTypes and OUI-based protocol types. 16-bit EtherTypes also occur in the Generic Routing Encapsulation (GRE) [RFC2784] header and in the Generic Network Virtualization Encapsulation (Geneve) [RFC8926] encapsulation header.

3.1. Ethernet Protocol Assignment under the IANA OUI

Two-octet protocol numbers under the IANA OUI are available, as in

88-B7-00-00-5E-qq-qq

or

xx-xx-AA-AA-03-00-00-5E-qq-qq

where qq-qq is the protocol number.

A number of such assignments have been made out of the 2**16 protocol numbers available from 00-00-5E-00-00 to 00-00-5E-FF-FF (see [EthernetNum]). The extreme values of this range, 00-00-5E-00-00 and 00-00-5E-FF-FF, are reserved and require IESG Ratification for assignment (see Section 5.1). New assignments of protocol numbers (qq-qq) under the IANA OUI must meet the following requirements:

- the assignment must be for standards use (either for an IETF Standard or other standard related to IETF work),
- the protocol must include a version field at a fixed offset or an equivalent marking such that later versions can be indicated in a way recognizable by earlier versions,
- it must be documented in an Internet-Draft or RFC, and
- such protocol numbers are not to be assigned for any protocol that has an EtherType. (Either that EtherType can be used directly or, in the LSAPs case, using the SNAP SAP and putting an all-zeros "OUI" before the EtherType as described above.)

In addition, the Expert Review (or IESG Ratification for the two reserved values) must be obtained using the procedure specified in Section 5.1.

3.2. Documentation Protocol Number

0x0042 is a protocol number under the IANA OUI (that is, 00-00-5E-00-42) to be used as an example for documentation purposes.

4. Other OUI/CID-Based Parameters

Some IEEE 802 and other protocols provide for parameters based on an OUI or CID beyond those discussed above. Such parameters commonly consist of an OUI or CID plus one octet of additional value. They are called Organizationally Specific parameters (sometimes informally and less accurately referred to as "vendor specific"). They would look like

yy-yy-yy-zz

where yy-yy-yy is the OUI/CID and zz is the additional specifier. An example is the Cipher Suite Selector in [IEEE.802.11_2012].

Values may be assigned under the IANA OUI for other OUI-based parameter usage by Expert Review, except that, for each use, the additional specifier values consisting of all zero bits and all one bits (0x00 (00-00-5E-00) and 0xFF (00-00-5E-FF) for a one-octet specifier) are reserved and require IESG Ratification (see Section 5.1) for assignment; also, the additional specifier value 0x42 (00-00-5E-42 for a one octet specifier, right justified and filled with zeros on the left if the specifier is more than one octet) is assigned for use as an example in documentation.

Assignments of other IANA OUI-based parameters must be for standards use (either for an IETF Standard or other standard related to IETF work) and be documented in an Internet-Draft or RFC. The first time a value is assigned for a particular parameter of this type, an IANA registry will be created to contain that assignment and any subsequent assignments of values for that parameter under the IANA OUI. The Expert may specify the name of the registry.

If different policies from those above are required for such a parameter, a BCP or Standards Track RFC should be adopted to update this BCP and specify the new policy and parameter.

4.1. LLDP IETF Organizationally Specific TLV Type

An example of an "other IANA OUI-based parameter" is specified in [RFC8520]. This provides for an Organizationally Specific TLV type for announcing a Manufacturer Usage Description (MUD) Uniform Resource Locator (URL) in the IEEE Link Local Discovery Protocol (LLDP) [IEEE802.1AB]. Additional IETF use of code points in this space have been proposed [BGP11dp]. (See also Section 5.8.)

5. IANA Considerations

This document concerns IANA considerations for the assignment of Ethernet parameters in connection with the IANA OUI and related matters.

> Note: The "IANA OUI Ethernet Numbers" registry group (web page) is for registries of numbers assigned under the IANA OUI, while the "IEEE 802 Numbers" registry group has informational lists of numbers assigned by the IEEE Registration Authority.

This document does not create any new IANA registries.

The MAC address values assigned for documentation and the protocol number for documentation were both assigned by [RFC7042].

No existing assignment is changed by this document.

5.1. Expert Review and IESG Ratification

This section specifies the procedures for Expert Review and IESG Ratification of MAC, protocol, and other IANA OUI-based identifiers. The Expert(s) referred to in this document shall consist of one or more persons appointed by and serving at the pleasure of the IESG.

5.1.1. Expert Review Guidance

The procedure described for Expert Review assignments in this document is consistent with the IANA Expert Review policy described in [RFC8126].

While finite, the universe of MAC code points from which Expert-judged assignments will be made is felt to be large enough that the requirements given in this document and the Experts' good judgment are sufficient guidance. The idea is for the Expert to provide a light sanity check for small assignments of MAC identifiers, with increased scrutiny by the Expert for medium-sized assignments of MAC identifiers and assignments of protocol identifiers and other IANA OUI-based parameters.

5.1.2. Expert Review and IESG Ratification Procedure

It can make sense to assign very large portions of the MAC identifier code point space. (Note that existing assignments include one for half of the entire multicast IANA 48-bit code point space and one for a sixteenth of that multicast code point space.) In those cases, and in cases of the assignment of "reserved" values, IESG Ratification of an Expert Review approval recommendation is required, as described below. This can be viewed as a combination of Expert Review and IESG Approval, as defined in [RFC8126]. IESG Approval is required only when the Expert does not reject the request. The procedure is as follows:

The applicant always completes the appropriate template from Appendix A below and sends it to IANA <iana@iana.org>.

IANA always sends the template to an appointed Expert. If the Expert recuses themselves or is non-responsive, IANA may choose an alternative appointed Expert or, if none is available, will contact the IESG.

In all cases, if IANA receives a disapproval from an Expert selected to review an application template, the application will be denied. The Expert should provide a reason for refusal, which IANA will communicate back to the applicant.

If the assignment is based on Expert Review:

If IANA receives approval and code points are available, IANA will make the requested assignment.

If the assignment is based on IESG Ratification:

The procedure starts with the first steps above for Expert Review. If the Expert disapproves the application, they simply inform IANA, who in turn informs the applicant that their request is denied; however, if the Expert believes the application should be approved or is uncertain and believes that the circumstances warrant the attention of the IESG, the Expert will inform IANA about their advice, and IANA will forward the application, together with the reasons provided by the Expert for approval or uncertainty, to the IESG. The IESG must decide whether the assignment will be granted. This can be accomplished by a management item in an IESG telechat, as is done for other types of requests. If the IESG decides not to ratify a favorable opinion by the Expert or decides against an application where the Expert is uncertain, the application is denied; otherwise, it is granted. The IESG will communicate its decision to the Expert and to IANA. In case of refusal, the IESG should provide a reason, which IANA will communicate to the applicant.

5.2. IANA Registry Group (Web Page) Name Changes

For clarity and parallelism with the IANA "IEEE 802 Numbers" registry group, the IANA "Ethernet Numbers" registry group is re-named the "IANA OUI Ethernet Numbers" registry.

As this document obsoletes [RFC7042], references to [RFC7042] in IANA registries in both the "IEEE 802 Numbers" and the "IANA OUI Ethernet Numbers" registry groups will be replaced by references to RFC 9542. Other IANA registry references to [RFC7042] are not changed.

5.3. MAC Address AFNs and RRTYPEs

IANA has assigned Address Family Numbers (AFNs) for MAC addresses as follows:

AFN	Decimal	Hex	Reference
48-bit MAC	16389	0x4005	[RFC7042]
64-bit MAC	16390	0x4006	[RFC7042]
24-bit OUI	16391	0x4007	[RFC7961]
Lower 24 bits of a 48-bit MAC address:			
MAC/24	16392	0x4008	[RFC7961]
Lower 40 bits of a 64-bit MAC address:			
MAC/40	16393	0x4009	[RFC7961]

Table 4

IANA has assigned DNS RRTYPEs [RFC6895] for MAC addresses as follows:

	RRTYPE Code			
Data	**Mnemonic**	**Decimal**	**Hex**	**Reference**
48-bit MAC	EUI48	108	0x006C	[RFC7043]
64-bit MAC	EUI64	109	0x006D	[RFC7043]

Table 5

5.4. Informational IANA Registry Group Material

IANA maintains an informational registry group, currently implemented as a web page, concerning EtherTypes, OUIs, and multicast addresses assigned under OUIs other than the IANA OUI. The title of this informational registry group is "IEEE 802 Numbers". IANA will update that informational registry group when changes are provided by or approved by the Expert(s).

5.5. EtherType Assignment Process

Applying to the IEEE Registration Authority for an EtherType needed by an IETF protocol requires IESG Approval, as stated in Appendix B. To minimize confusion, this process will normally be done by the primary expert for the informational "EtherType" registry within the "IEEE 802 Numbers" registry group, as described below (see also Section 5.4).

After IESG Approval of the requirement for an EtherType, the IESG should refer the matter to IANA. In any case, IANA will ask the "EtherType" registry expert to execute the IEEE Registration Authority [IEEE_RA] EtherType request process. This path is specified because the IESG usually deals with IANA for assignment actions and because IANA should be aware of which "EtherType" registry expert(s) are available, normally referring the making of the EtherType assignment request to the primary expert.

Here is sample text for an Internet-Draft where both IANA and IEEE assignments are required, where "YYY" would be replaced by an explanation of for what/why the EtherType is needed in whatever level of detail is necessary and would normally include a reference or references to other appropriate parts of the Internet-Draft:

> X. Assignment Considerations
>
> X.1. IEEE Assignment Considerations
>
> > The IESG is requested to approve applying to the IEEE Registration Authority for an EtherType for YYY. (The IESG should communicate its approval to IANA and to those concerned with this document. IANA will forward the IESG Approval to the registry expert of the "EtherType" registry from the "IEEE 802 Numbers" registry group who will make the application to the IEEE Registration Authority, keeping IANA informed.)
>
> X.2. IANA Considerations

...

5.6. OUI Exhaustion

When the available space for either multicast or unicast EUI-48 identifiers under OUI 00-00-5E has been 90% or more exhausted, IANA should request an additional OUI from the IEEE Registration Authority for further IANA assignment. The appointed Expert(s) should monitor for this condition and notify IANA.

5.7. IANA OUI MAC Address Table

The following changes are made by this document to the Notes for the "IANA Unicast 48-bit MAC Addresses", the "IANA Multicast 48-bit MAC Addresses", and the "IANA 64-bit MAC Addresses" registries. In addition, the references in those registries are updated, as specified in Section 5.2.

The Notes for the "IANA Unicast 48-bit MAC Addresses" registry and for the "IANA Multicast 48-bit MAC Addresses" registry are changed to the following:

> These values are prefixed with 00-00-5E. See Section 2.1.5 of RFC 9542.

The Note for the "IANA 64-bit MAC Addresses" registry is changed to the following:

> These values are prefixed with 00-00-5E to form unicast MAC addresses, with 01-00-5E to form multicast MAC addresses, with 02-00-5E to form unicast modified EUI-64 addresses, and with 03-00-5E to form multicast modified EUI-64 addresses. See RFC 9542, particularly Section 2.2.2, for more details.

5.8. IANA LLDP TLV Subtypes

IANA is requested to move the "IANA Link Layer Discovery Protocol (LLDP) TLV Subtypes" registry from the "IEEE 802 Numbers" registry group to the "IANA OUI Ethernet Numbers" registry group, since code points within it are assigned by IANA, and to add RFC 9542 as an additional reference for that registry.

In addition, IANA is requested to update three entries in that registry as follows:

Value	Description	Reference
0	Reserved	RFC 9542
42	Example for use in documentation	RFC 9542

Value	Description	Reference
255	Reserved	RFC 9542

Table 6

The entries for 1 (MUD), 2-41 (unassigned), and 43-254 (unassigned) are unchanged.

5.9. CBOR Tag Assignments

IANA has assigned two CBOR Tags as shown below in the "Concise Binary Object Representation (CBOR) Tags" registry.

Tag	Data Item	Semantics	Reference
48	byte string	IEEE MAC Address	RFC 9542
1048	byte string	IEEE OUI/CID	RFC 9542

Table 7

6. Security Considerations

This document is concerned with assignment of IEEE 802 parameters allocated to IANA, particularly those under the IANA OUI, and closely related matters. It is not directly concerned with security except as follows:

> Confusion and conflict can be caused by the use of MAC addresses or other OUI-derived protocol parameters as examples in documentation. Examples that are "only" to be used in documentation can end up being coded and released or cause conflicts due to later real use and the possible acquisition of intellectual property rights in such addresses or parameters. The reservation herein of MAC addresses and parameters for documentation purposes will minimize such confusion and conflict.

MAC addresses are identifiers provided by a device to the network. On certain devices, MAC addresses are not static and can be configured. The network should exercise caution when using these addresses to enforce policy because addresses can be spoofed and previously seen devices can return to the network with a new address.

MAC addresses identify a physical or virtual interface and can be used for tracking the device with that interface. Thus, they can be used to track users associated with that device. See [madinas] for related privacy considerations and a discussion of MAC address randomization to partially mitigate this threat. Also, see [RFC7043] for the security and privacy considerations of publishing MAC addresses in DNS.

7. References

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Appendix A. Templates

This appendix provides the specific templates for IANA assignments of parameters. Explanatory words in parentheses in the templates below may be deleted in a completed template as submitted to IANA.

A.1. EUI-48/EUI-64 Identifier or Identifier Block Template

Applicant Name:

Applicant Email:

Applicant Telephone: (starting with the country code)

Use Name: (brief name of Parameter use, such as "Foo Protocol" [RFC3092])

Document: (I-D or RFC specifying use to which the identifier or block of identifiers will be put)

Specify whether this is an application for EUI-48 or EUI-64 identifiers:

Size of Block requested: (must be a power-of-two-sized block, can be a block of size one (2**0))

Specify multicast, unicast, or both:

A.2. IANA OUI/CID-Based Protocol Number Template

Applicant Name:

Applicant Email:

Applicant Telephone: (starting with the country code)

Use Name: (brief name of use of code point, such as "Foo Protocol")

Document: (I-D or RFC specifying use to which the protocol identifier will be put)

Note: (any additional note)

A.3. Other IANA OUI/CID-Based Parameter Template

Applicant Name:

Applicant Email:

Applicant Telephone: (starting with the country code)

Protocol where the OUI/CID-Based Parameter for which a value is being requested appears: (such as Cipher Suite selection in IEEE 802.11)

Use Name: (brief name of use of code point to be assigned, such as "Foo Cipher Suite" [RFC3092])

Document: (I-D or RFC specifying use to which the other IANA OUI-based parameter value will be put)

Note: (any additional note)

Appendix B. EtherTypes

This appendix provides a copy of the IESG Statement issued in May 2023 on obtaining new IETF EtherTypes in Appendix B.1. Note that there is an informational IANA registry of some important EtherTypes specified for IETF protocols or by IEEE 802 available, currently at [IANA]. The IEEE Registration Authority page on EtherTypes <https://standards.ieee.org/regauth/ethertype/eth.txt> may also be useful. See Section 3 above.

B.1. IESG Statement on EtherTypes

From: IESG
Date: 1 May 2023

The IEEE Registration Authority (IEEE RA) assigns EtherTypes with oversight from the IEEE Registration Authority Committee (IEEE RAC)

(See <https://standards.ieee.org/products-programs/regauth/ethertype/>.) Some IETF protocol specifications make use of EtherTypes. All EtherType applications are subject to IEEE RA technical review for consistency with policy.

Since EtherTypes are a fairly scarce resource, the IEEE RAC has let us know that they will not assign a new EtherType to a new IETF protocol specification until the IESG has approved the protocol specification for publication as an RFC. In exceptional cases, the IEEE RA is willing to consider "early allocation" of an EtherType for an IETF protocol that is still under development as long as the request comes from and has been vetted by the IESG.

To let the IEEE RAC know that the IESG has approved the request for an Ethernet assignment for an IETF protocol, all future requests for assignment of EtherTypes for IETF protocols will be made by the IESG.

Note that Local Experimental ("playpen") EtherTypes have been assigned in IEEE 802 [IEEE802_OandA] for use during protocol development and experimentation.

Appendix C. Changes from RFC 7042

This document obsoletes [RFC7042] and makes the changes listed below. However, the completed application template based upon which an IANA OUI-based protocol number value was assigned for document use remains that in Appendix C of [RFC7042].

- Add information on MA-M (28-bit) and MA-S (36-bit) EUI prefixes that the IEEE Registration Authority assigns.
- Add information on the restructuring of the "local" MAC address space into four quadrants under the Structured Local Address Plan (SLAP) [IEEE802_OandA].
- Include the IESG Statement on EtherTypes (see Appendix B.1) and more detailed IETF procedures for applying to the IEEE Registration Authority for an EtherType for use in an IETF protocol (see Section 5.5).
- Mention that IEEE 802 CFM code points have been allocated to the IETF (see Section 1.4).
- Mention the Organizationally Specific LLDP data element that has been assigned under the IANA OUI and the registry set up for future such assignments (see Section 4.1).
- Clarify minor details in Section 5.1 on Expert Review and IESG Ratification.
- Specify CBOR tags for MAC addresses and OUIs/CIDs (see Section 2.4).
- Add a version field requirement for the allocation of protocol numbers under the IANA OUI (see Section 3.1).
- Mention that EtherTypes are used in the Geneve [RFC8926] encapsulation header (see Section 3).
- Add "a combination of Expert Review and IESG Approval" as part of the specification for "IESG Ratification".

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