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Guidelines for Creating New DHCPv6 Options
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Abstract

This document provides guidance to prospective DHCPv6 Option developers to help them creating option formats that are easily adoptable by existing DHCPv6 software. It also provides guidelines for expert reviewers to evaluate new registrations. This document updates RFC3315.

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1. Requirements Language

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

2. Introduction

Most protocol developers ask themselves if a protocol will work, or work efficiently. These are important questions, but another less frequently considered question is whether the proposed protocol presents itself needless barriers to adoption by deployed software.

DHCPv6 [RFC3315] software implementors are not merely faced with the task of handling a given option's format on the wire. The option must fit into every stage of the system's process, starting with the user interface used to enter the configuration up to the machine interfaces where configuration is ultimately consumed.

Another frequently overlooked aspect of rapid adoption is whether the option requires operators to be intimately familiar with the option's internal format in order to use it? Most DHCPv6 software provides a facility for handling unknown options at the time of publication. The handling of such options usually needs to be manually configured by the operator. But if doing so requires extensive reading (more than can be covered in a simple FAQ for example), it inhibits adoption.

So although a given solution would work, and might even be space, time, or aesthetically optimal, a given option is presented with a series of ever-worsening challenges to be adopted:

- If it doesn't fit neatly into existing config files.
- If it requires source code changes to be adopted, and hence upgrades of deployed software.
- If it does not share its deployment fate in a general manner with other options, standing alone in requiring code changes or reworking configuration file syntaxes.

- o If the option would work well in the particular deployment environment the proponents currently envision, but has equally valid uses in some other environment where the proposed option format would fail or would produce inconsistent results.

There are many things DHCPv6 option creators can do to avoid the pitfalls in this list entirely, or failing that, to make software implementors lives easier and improve its chances for widespread adoption.

This document is envisaged as a help for protocol developers that define new options and for expert reviewers that review submitted proposals.

3. When to Use DHCPv6

Principally, DHCPv6 carries configuration parameters for its clients. Any knob, dial, slider, or checkbox on the client system, such as "my domain name servers", "my hostname", or even "my shutdown temperature" are candidates for being configured by DHCPv6.

The presence of such a knob isn't enough, because DHCPv6 also presents the extension of an administrative domain - the operator of the network to which the client is currently attached. Someone runs not only the local switching network infrastructure that the client is directly (or wirelessly) attached to, but the various methods of accessing the external Internet via local assist services that the network must also provide (such as domain name servers, or routers). This means that, even if a configuration parameter can potentially delivered by DHCPv6, it is necessary to evaluate whether it is reasonable for this parameter to be under the control of the administrator of whatever network a client is attached to at any given time.

Note that the client is not required to configure any of these values received via DHCPv6 (e.g., due to having these values locally configured by its own administrator). But it needs to be noted that overriding DHCPv6-provided values may cause the client to be denied certain services in the network to which it has attached. The possibility of having higher level of control over client node configuration is one of the reasons that DHCPv6 is preferred in enterprise networks.

4. General Principles

The primary guiding principle to follow in order to enhance an option's adoptability is reuse. The option should be created in such a way that does not require any new or special case software to

support. If old software currently deployed and in the field can adopt the option through supplied configuration facilities then it's fairly certain that new software can easily formally adopt it.

There are at least two classes of DHCPv6 options: simple options which are provided explicitly to carry data from one side of the DHCPv6 exchange to the other (such as nameservers, domain names, or time servers), and a protocol class of options which require special processing on the part of the DHCPv6 software or are used during special processing (such as the Fully Qualified Domain Name (FQDN) option [RFC4704]), and so forth; these options carry data that is the result of a routine in some DHCPv6 software.

The guidelines laid out here should be applied in a relaxed manner for the protocol class of options. Wherever special case code is already required to adopt the DHCPv6 option, it is substantially more reasonable to format the option in a less generic fashion, if there are measurable benefits to doing so.

5. Reusing Other Options Formats

The easiest approach to manufacturing trivially deployable DHCPv6 Options is to assemble the option out of whatever common fragments fit - possibly allowing a group of data elements to repeat to fill the remaining space (if present) and so provide multiple values. Place all fixed size values at the start of the option, and any variable/indeterminate sized value at the tail end of the option.

This means that implementations will likely be able to reuse code paths designed to support the other options.

There is a tradeoff between the adoptability of previously defined option formats, and the advantages that new or specialized formats can provide. In general, it is usually preferable to reuse previously used option formats.

However, it isn't very practical to consider the bulk of DHCPv6 options already allocated, and consider which of those solve a similar problem. So, the following list of common option format data elements is provided as a shorthand. Please note that it is not complete in terms of exampling every option format ever devised.

If more complex options are needed, those basic formats mentioned here may be considered as primitives (or 'fragment types') that can be used to build more complex formats. It should be noted that it is often easier to implement two options with trivial formats than one option with more complex format. That is not unconditional requirement though. In some cases splitting one complex option into

two or more simple options introduces inter-option dependencies that should be avoided. In such a case, it is usually better to keep one complex option.

5.1. Option with IPv6 addresses

This option format is used to carry one or many IPv6 addresses. In some cases the number of allowed address is limited (e.g. to one):

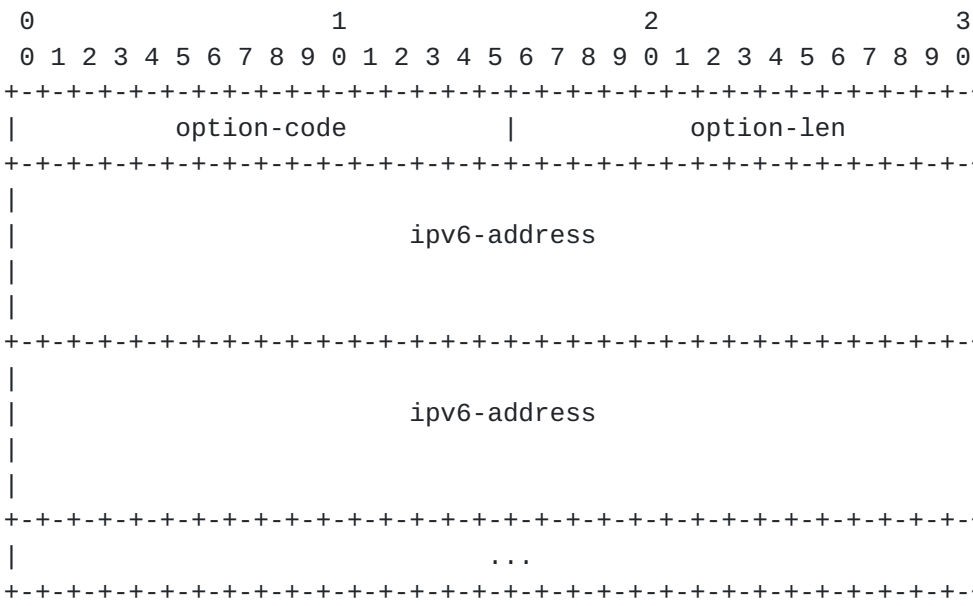


Figure 1: Option with IPv6 address

Examples of use:

- DHCPv6 server unicast address (a single address only) [RFC3315]
- SIP Servers IPv6 Address List [RFC3319]
- DNS Recursive Name Server [RFC3646]
- NIS Servers [RFC3898]
- SNTP Servers [RFC4075]
- Broadcast and Multicast Service Controller IPv6 Address Option for DHCPv6 [RFC4280]
- MIPv6 Home Agent Address [RFC6610] (a single address only)
- NTP server [RFC5908] (a single address only)

o NTP Multicast address [RFC5908] (a single address only)

5.2. Option with a single flag (boolean)

Sometimes it is useful to convey a single flag that can take either on or off values. Instead of specifying an option with one bit of usable data and 7 bits of padding, it is better to define an option without any content. It is the presence or absence of the option that conveys the value. This approach has the additional benefit of absent option designating the default, i.e. administrator has to take explicit actions to deploy the opposite of the default value.

The absence of the option represents the default value and the presence of the option represents the other value, but that this does not necessarily mean that absence is "off" (or "false") and presence is "on" (or "true"). That is, if it's desired that the default value for a bistable option is "true"/"on", then the presence of that option would turn it off (make it false). If the option presence signifies off/false state, that should be refleced in the option name, e.g. OPTION_DISABLE_FOO.

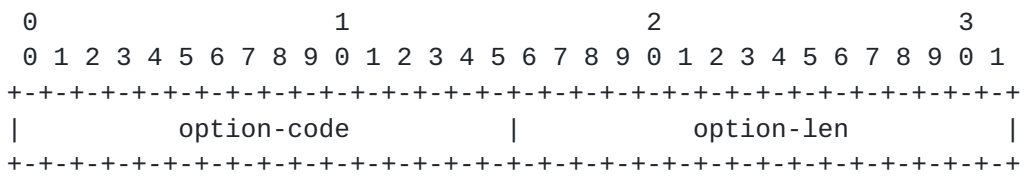


Figure 2: Option for conveying boolean

Examples of use:

o DHCPv6 rapid-commit [RFC3315]

5.3. Option with IPv6 prefix

Sometimes there is a need to convey an IPv6 prefix. The information to be carried by such an option includes the 128-bit IPv6 prefix together with a length of this prefix taking values from 0 to 128. Using the simplest approach, the option could convey this data in two fixed length fields: one carrying prefix length, another carrying the prefix. However, in many cases /64 or shorter prefixes are used. This implies that the large part of the prefix data carried by the option would have its bits set to zero and would be unused. In order to avoid carrying unused data, it is recommended to store prefix in the variable length data field. The appropriate option format is defined as follows:

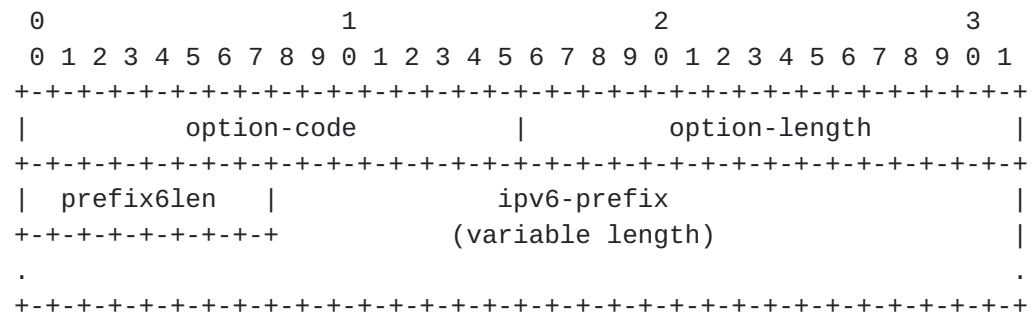


Figure 3: Option with IPv6 Prefix

option-length is set to 1 + length of the IPv6 prefix.

prefix6len is one octet long and specifies the length in bits of the IPv6 prefix. Typically allowed values are 0 to 128.

ipv6-prefix field is a variable length field that specifies the IPv6 prefix. The length is (prefix6len + 7) / 8. This field is padded with zero bits up to the nearest octet boundary when prefix6len is not divisible by 8.

Examples of use:

o Default Mapping Rule [I-D.ietf-softwire-map-dhcp]

For example, the prefix 2001:db8::/60 would be encoded with an option-length of 9, prefix6-len would be set to 60, the ipv6-prefix would be 8 octets and would contain octets 20 01 0d b8 00 00 00 00.

It should be noted that the IAPREFIX option defined by [RFC3633] uses a full length 16-octet prefix field. The concern about option length was not well understood at the time of its publication.

5.4. Option with 32-bit integer value

This option format can be used to carry 32 bit-signed or unsigned integer value:

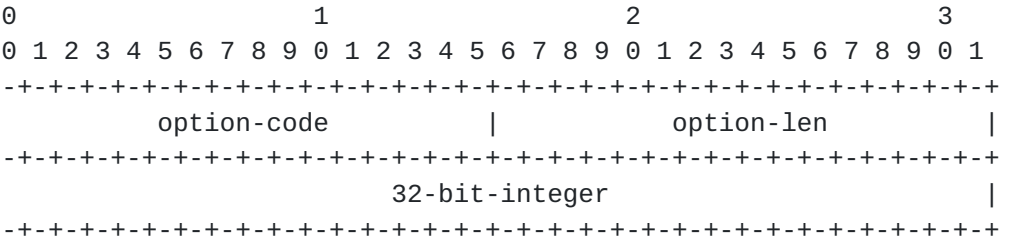


Figure 4: Option with 32-bit-integer value

Examples of use:

o Information Refresh Time [RFC4242]

5.5. Option with 16-bit integer value

This option format can be used to carry 16-bit signed or unsigned integer values:

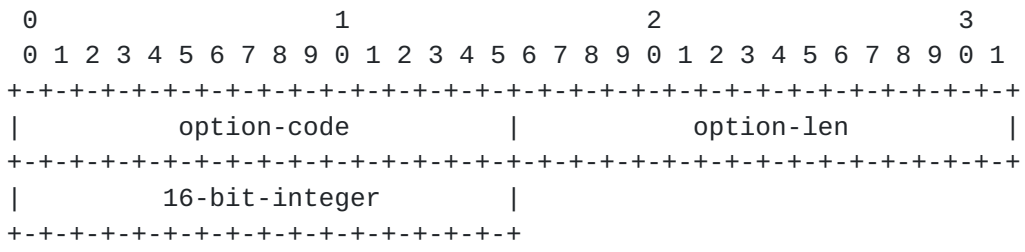


Figure 5: Option with 16-bit integer value

Examples of use:

o Elapsed Time [RFC3315]

5.6. Option with 8-bit integer value

This option format can be used to carry 8-bit integer values:

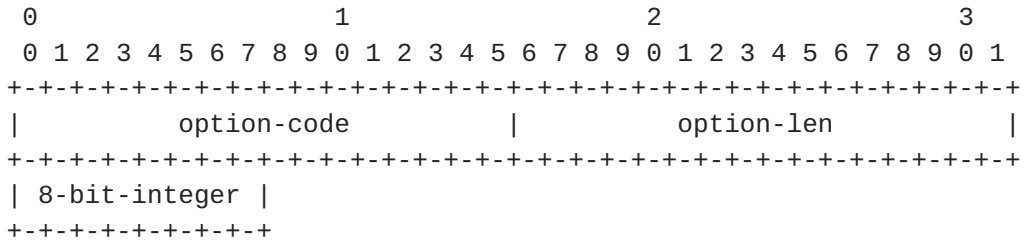


Figure 6: Option with 8-bit integer value

Examples of use:

o DHCPv6 Preference [RFC3315]

5.7. Option with URI

A Uniform Resource Identifier (URI) [RFC3986] is a compact sequence of characters that identifies an abstract or physical resource. The term "Uniform Resource Locator" (URL) refers to the subset of URIs that, in addition to identifying a resource, provide a means of locating the resource by describing its primary access mechanism

(e.g., its network "location"). This option format can be used to carry a single URI:

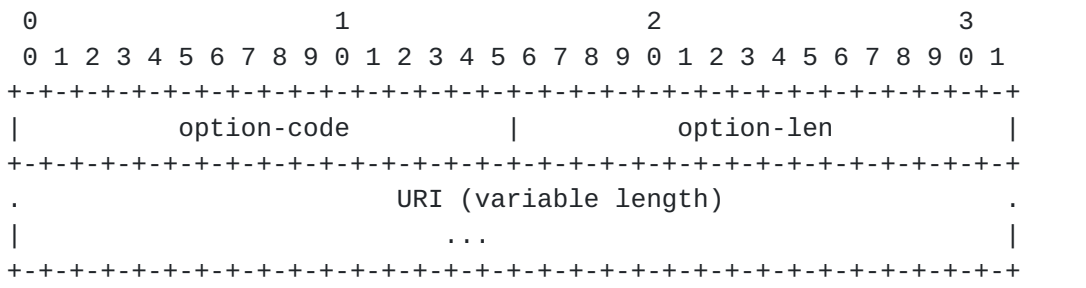


Figure 7: Option with URI

Examples of use:

o Boot File URL [RFC5970]

An alternate encoding to support multiple URIs is available. An option must be defined to use either the single URI format above or the multiple URI format below depending on whether a single is always sufficient or if multiple URIs are possible.

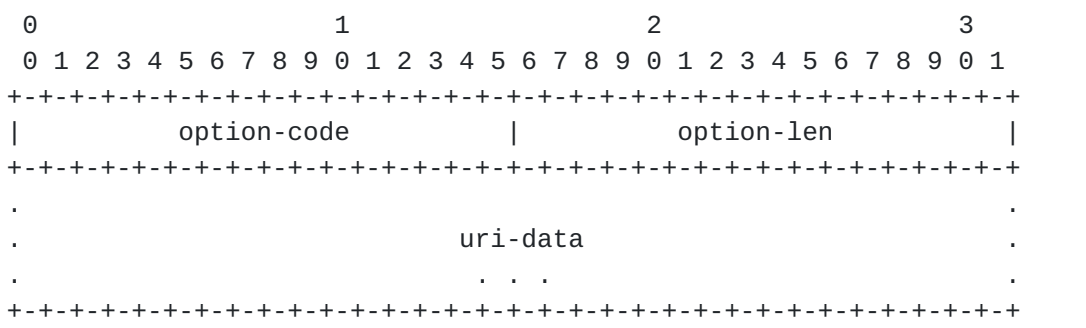
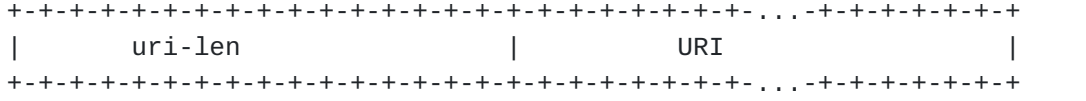


Figure 8: Option with multiple URIs

Each instance of the uri-data is formatted as follows:



The uri-len is two octets long and specifies the length of the uri data. Although URI format in theory supports up to 64k of data, in practice large chunks of data may be problematic. See Section 15 for details.

5.8. Option with Text String

A text string is a sequence of characters that have no semantics. The encoding of the text string MUST be specified. Unless otherwise specified, all text strings in newly defined options are expected to be Unicode strings that are encoded using UTF-8 [RFC3629] in Net-Unicode form [RFC5198]. Please note that all strings containing only 7 bit ASCII characters are also valid UTF-8 Net-Unicode strings.

If a data format has semantics other than just being text, it is not a string. E.g., a FQDN is not a string, and a URI is also not a string, because they have different semantics. A string must not include any terminator (such as a null byte). The null byte is treated as any other character and does not have any special meaning. This option format can be used to carry a text string:

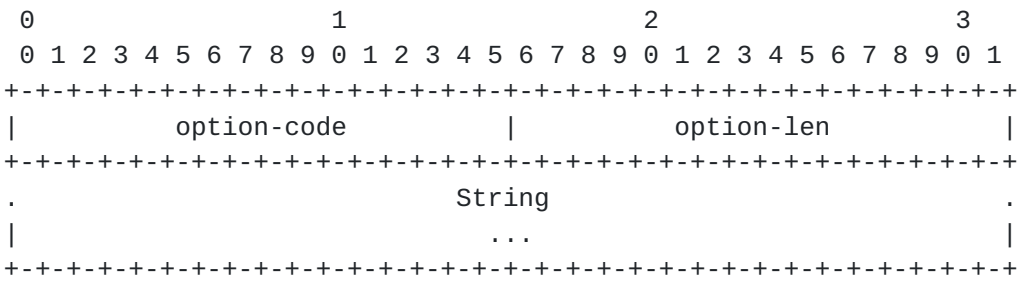


Figure 9: Option with text string

Examples of use:

o Timezone Options for DHCPv6 [RFC4833]

An alternate encoding to support multiple text strings is available. An option must be defined to use either the single text string format above or the multiple text string format below depending on whether a single is always sufficient or if multiple text strings are possible.

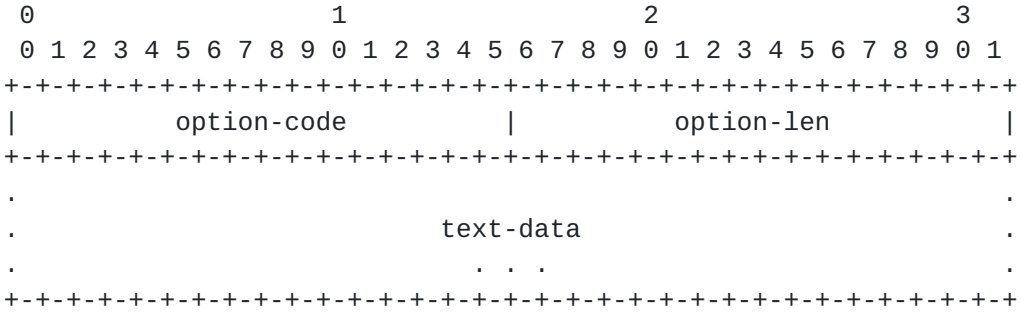
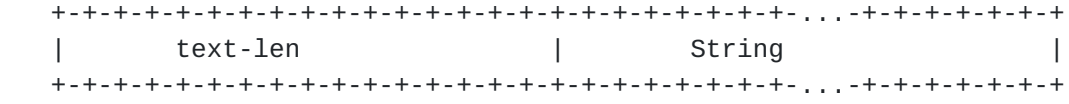


Figure 10: Option with multiple text strings

Each instance of the text-data is formatted as follows:



The text-len is two octets long and specifies the length of the string.

5.9. Option with variable length data

This option can be used to carry variable length data of any kind. Internal representation of carried data is option specific. Whenever this format is used by the new option being defined, the data encoding should be documented.

This option format provides a lot of flexibility to pass data of almost any kind. Though, whenever possible it is highly recommended to use more specialized options, with field types better matching carried data types.

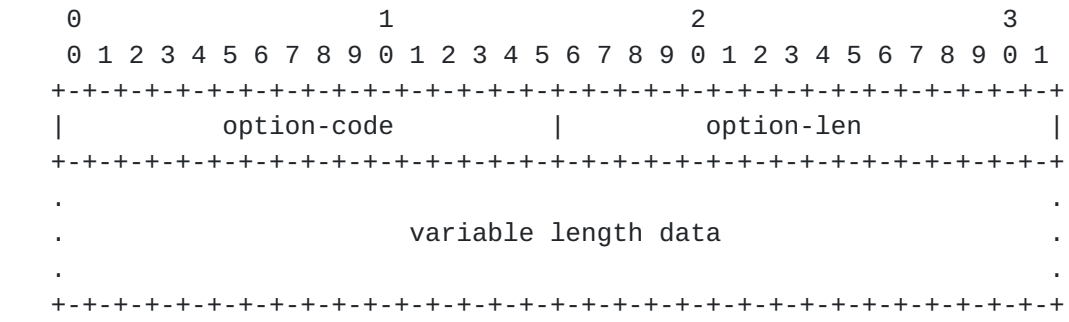


Figure 11: Option with variable length data

Examples of use:

- Client Identifier [RFC3315]

- Server Identifier [RFC3315]

5.10. Option with DNS Wire Format Domain Name List

This option is used to carry 'domain search' lists or any host or domain name. It uses the same format as described in Section 5.9, but with the special data encoding, described in section 8 of [RFC3315]. This data encoding supports carrying multiple instances of hosts or domain names in a single option, by terminating each instance with the byte value of 0.

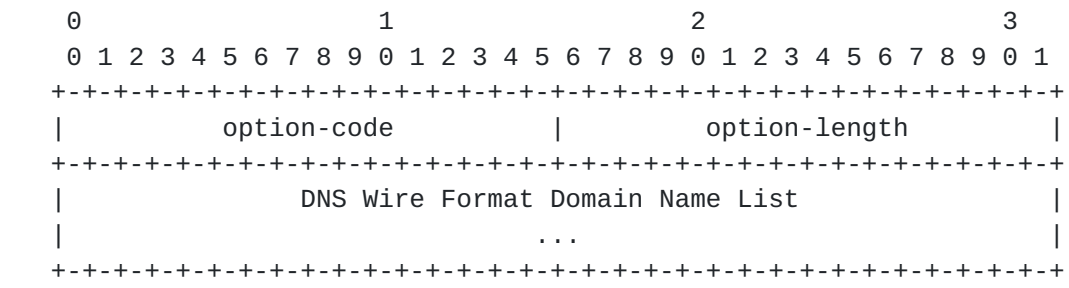


Figure 12: Option with DNS Wire Format Domain Name List

Examples of use:

- SIP Servers Domain Name List [RFC3319] (many domains)
- NIS Domain Name (many domains) [RFC3898] (many domains)
- LoST Server Domain name [RFC5223]
- LIS Domain name [RFC5986]
- DS-Lite AFTR location [RFC6334] (a single FQDN)
- Home Network Identifier [RFC6610] (a single FQDN)
- Home Agent FQDN [RFC6610] (a single FQDN)

6. Avoid Conditional Formatting

Placing an octet at the start of the option which informs the software how to process the remaining octets of the option may appear simple to the casual observer. But the only conditional formatting methods that are in widespread use today are 'protocol' class options. Therefore conditional formatting requires new code to be written and complicates future interoperability should new conditional formats be added; and existing code has to ignore conditional format that it does not support.

7. Avoid Aliasing

Options are said to be aliases of each other if they provide input to the same configuration parameter. A commonly proposed example is to configure the location of some new service ("my foo server") using a binary IP address, a domain name field, and an URL. This kind of aliasing is undesirable, and is not recommended.

In this case, where three different formats are supposed, it more than triples the work of the software involved, requiring support for

not merely one format, but support to produce and digest all three. Furthermore, code development and testing must cover all possible combinations of defined formats. Since clients cannot predict what values the server will provide, they must request all formats. So in the case where the server is configured with all formats, DHCPv6 message bandwidth is wasted on option contents that are redundant. Also, the DHCPv6 option number space is wasted, as three new option codes are required, rather than one.

It also becomes unclear which types of values are mandatory, and how configuring some of the options may influence the others. For example, if an operator configures the URL only, should the server synthesize a domain name and IP address?

A single configuration value on a host is probably presented to the operator (or other software on the machine) in a single field or channel. If that channel has a natural format, then any alternative formats merely make more work for intervening software in providing conversions.

So the best advice is to choose the one method that best fulfills the requirements, be that for simplicity (such as with an IP address and port pair), late binding (such as with DNS), or completeness (such as with a URL).

8. Choosing between FQDN and address

Some parameters may be specified as FQDN or an address. In most cases one or the other should be used. This section discusses pros and cons of each approach and is intended to help make an informed decision in that regard. It is strongly discouraged to define both option types at the same time (see Section 7), unless there is sufficient motivation to do so.

There is no single recommendation that works for every case. It very much depends on the nature of the parameter being configured. For parameters that are network specific or represent certain aspects of network infrastructure, like available mobility services, in most cases address is more usable choice. For parameters that can be considered application specific configuration, like SMTP servers our SIP servers, it is usually better to use FQDN.

Applications are often better suited to deal with FQDN failures than with address failures. Most operating systems provide a way to retry FQDN resolution if previous attempt fails. That type of error recovery is supported by great number of applications. On the other hand, there is typically no API availble for applications to reconfigure over DHCP to get a new address value if the one received

is no longer appropriate. This problem may be usually addressed by providing a list of addresses, rather than just a single one. That, on the other hand, requires defined procedure how multiple addresses should be used (all at once, round robin, try first and fail over to the next if it fails etc.).

On the specific subject of desiring to configure a value using a FQDN instead of an address, note that most DHCPv6 server implementations will accept a Domain Name entered by the administrator, and use DNS resolution to render binary IP addresses in DHCPv6 replies to clients. Consequently, consider the extra packet overhead incurred on the client's end to perform DNS resolution itself. The client may be operating on a battery and packet transmission is a small drain of battery power (usually negligible if done once, but repeated many times may become significant), and the extra RTT delays the client must endure before the service is configured are at least two factors to consider in making a decision on format.

Addresses have a benefit of being easier to implemented and handle by the DHCP software. An address option is simpler to use, its validation is trivial (multiple of 16 constitutes a valid option), is explicit and does not allow any ambiguity. It is faster (does not require extra round trip time), so it is more efficient, which can be especially important for energy restricted devices. It also does not require that the client implement DNS resolution.

FQDN provide a higher level of indirection and ambiguity. In many cases that may be considered a benefit, but can be considered a flaw in others. For example, one operator suggested to have the same name being resolved to different addresses depending on the point of attachement of the host doing resolution. This is one way to provide localized addressing. However, in order to do this, it is necessary to violate the DNS convention that a query on a particular name should always return the same answer (aside from ordering of IP addresses in the response, which is supposed to be varied by the name server). This same locality of reference for configuration information can be achieved directly using DHCP, since the DHCP server must know the network topology in order to provide IP address or prefix configuration.

The other type of ambiguity is related to multiple provisioning domains (see Section 12). The stub resolver on the DHCP client cannot at present be assumed to make the DNS query for a DHCP-supplied FQDN on the same interface on which it received its DHCP configuration, and may therefore get a different answer from the DNS than was intended.

This is particularly a problem when the normal expected use of the option makes sense with private DNS zone(s), as might be the case on an enterprise network. It may also be the case that the client has an explicit DNS server configured, and may therefore never query the enterprise network's internal DNS server.

FQDN does require a resolution into an actual address. This implies the question when the FQDN resolution should be taken. There are a couple of possible answers: a) by the server, when it is started, b) by the server, when it is about to send an option, c) by the client, immediately after receiving an option, d) by the client, when the content of the option is actually consumed. For a), b) and possibly c), the option should really convey an address, not FQDN. The only real incentive to use FQDN is case d). It is the only case that allows possible changes in the DNS to be picked up by clients.

FQDN imposes a number of additional failure modes and issues that should be dealt with:

1. The client must have a knowledge about available DNS servers. That typically means that DNS_SERVERS option [RFC3646] will be used, i.e. client should request DNS_SERVERS in its Option Request Option. This should be mentioned in the draft that defines new option. It is possible that the server will return FQDN option, but not the DNS Servers option. There should be a brief discussion about it;

2. The DNS may not be reachable;

3. DNS may be available, but may not have appropriate information (e.g. no AAAA records for specified FQDN);

4. Address family must be specified (A, AAAA or any); the information being configured may require specific address family (e.g. IPv6), but there may be a DNS record only of another type (e.g. A only with IPv4 address).

5. What should the client do if there are multiple records available (use only the first one, use all, use one and switch to the second if the first fails for whatever reason, etc.); This may be an issue if there is an expectation that the parameter being configured will need exactly one address;

6. Multi-homed devices may be connected to different administrative domains with each domain providing different information in DNS (e.g. an enterprise network exposing private domains). Client may send DNS queries to a different DNS server;

7. It should be mentioned if Internationalized Domain Names are allowed. If they are, what kind of DNS option encoding should be specified.

If the parameter is expected to be used by constrained devices (low power, battery operated, low capabilities) or in very lossy networks, it may be appealing to drop the requirement of having DNS resolution being performed and use addresses. Another example of a constrained device is a network booted device, where despite the fact that the node itself is very capable once it's booted, the boot prom is quite constrained.

Another aspect that should be considered is time required for the clients to notice any configuration changes. Consider a case where a server configures a service A using address and service B using fqdn. When an administrator decides to update the configuration, he or she can update DHCP server configuration to change both services. If the clients do not support reconfigure (which is an optional feature of RFC3315, but in some environments, e.g. cable modems, is mandatory), the configuration will be updated on clients after T1 timer. Depending on the nature of the change (is it a new server added to a cluster of already operating servers or a new server that replaces the only available server that crashed?), this may be an issue. On the other hand, updating service B may be achieved with DNS record update. That information may be cached by caching DNS servers for up to TTL. Depending on the values of T1 and TTL, one update may be faster than another. Furthermore, depending on the nature of the change (planned modification or unexpected failure), T1 or TTL may be lowered before the change to speed up new configuration adoption. Simply speaking protocol designers don't know what the TTL or the T1 time will be, so they can't make assumptions about whether a DHCP option will be refreshed more quickly based on T1 or TTL.

Address options that are used with overly long T1 (renew timer) values have some characteristics of hardcoding values. That is strongly discouraged. See [RFC4085] for an in depth discussion. If the option may appear in Information-Request, its lifetime should be controlled using information refresh time option [RFC4242].

One specific case that makes the choice between address and FQDN not obvious is a DNSSEC bootstrap scenario. DNSSEC validation imposes a requirement for clock sync (to the accuracy reasonably required to consider signature inception and expiry times). This often implies usage of NTP configuration. However, if the NTP is provided as FQDN, there is no way to validate its DNSSEC signature. This is somewhat weak argument though, as providing NTP server as an address is also not verifable using DNSSEC. If the thrustworthiness of the

configuration provided by DHCP server is in question, DHCPv6 offers authentication mechanisms that allow server authentication.

9. Encapsulated options in DHCPv6

Most options are conveyed in a DHCPv6 message directly. Although there is no codified normative language for such options, they are often referred to as top-level options. Many options may include other options. Such inner options are often referred to as encapsulated or nested options. Those options are sometimes called sub-options, but this term actually means something else, and therefore should never be used to describe encapsulated options. It is recommended to use term "encapsulated" as this terminology is used in [RFC3315]. The difference between encapsulated and sub-options are that the former uses normal DHCPv6 option numbers, while the latter uses option number space specific to a given parent option. It should be noted that, contrary to DHCPv4, there is no shortage of option numbers. Therefore almost all options share a common option space. For example option type 1 meant different things in DHCPv4, depending if it was located in top-level or inside of Relay Agent Information option. There is no such ambiguity in DHCPv6 (with the exception of [RFC5908], which SHOULD NOT be used as a template for future DHCP option definitions).

From the implementation perspective, it is easier to implement encapsulated options rather than sub-options, as the implementers do not have to deal with separate option spaces and can use the same buffer parser in several places throughout the code.

Such encapsulation is not limited to one level. There is at least one defined option that is encapsulated twice: Identity Association for Prefix Delegation (IA_PD, defined in [RFC3633], section 9) conveys IA Prefix (IAPREFIX, defined in [RFC3633], section 10). Such delegated prefix may contain an excluded prefix range that is represented by PD_EXCLUDE option that is conveyed as encapsulated inside IAPREFIX (PD_EXCLUDE, defined in [RFC6603]). It seems awkward to refer to such options as sub-sub-option or doubly encapsulated option, therefore "encapsulated option" term is typically used, regardless of the nesting level.

When defining a DHCP-based configuration mechanism for a protocol that requires something more complex than a single option, it may be tempting to group configuration values using sub-options. That should preferably be avoided, as it increases complexity of the parser. It is much easier, faster and less error prone to parse a large number of options on a single (top-level) scope, than parse options on several scopes. The use of sub-options should be avoided

as much as possible, but it is better to use sub-options rather than conditional formatting.

It should be noted that currently there is no clear way defined for requesting sub-options. Most known implementations are simply using top-level ORO for requesting both top-level options and encapsulated options.

10. Additional States Considered Harmful

DHCP is a protocol designed for provisioning clients. Less experienced protocol designers often assume that it is easy to define an option that will convey a different parameter for each client in a network. Such problems arose during designs of MAP [I-D.ietf-softwire-map-dhcp] and 4rd [I-D.ietf-softwire-4rd]. While it would be easier for provisioned clients to get ready to use per-client option values, such requirement puts exceedingly large loads on the server side. The new extensions may introduce new implementation complexity and additional database state on the server. Alternatives should be considered, if possible. As an example, [I-D.ietf-softwire-map-dhcp] was designed in a way that all clients are provisioned with the same set of MAP options and each provisioned client uses its unique address and delegated prefix to generate client-specific information. Such a solution does not introduce any additional state for the server and therefore scales better.

It also should be noted that contrary to DHCPv4, DHCPv6 keeps several timers for renewals. Each IA_NA (addresses) and IA_PD (prefixes) contains T1 and T2 timers that designate time after which client will initiate renewal. Those timers apply only to its own IA containers. Refreshing other parameters should be initiated after a time specified in the Information Refresh Time Option (defined in [RFC4242]), carried in the Reply message and returned in response to Information-Request message. Introducing additional timers make deployment unnecessarily complex and SHOULD be avoided.

11. Configuration changes occur at fixed times

In general, DHCPv6 clients only refresh configuration data from the DHCP server when the T1 timer expires. Although there is a RECONFIGURE mechanism that allows a DHCP server to request that clients initiate reconfiguration, support for this mechanism is optional and cannot be relied upon.

Even when DHCP clients refresh their configuration information, not all consumers of DHCP-sourced configuration data notice these changes. For instance, if a server is started using parameters

received in an early DHCP transaction, but does not check for updates from DHCP, it may well continue to use the same parameter indefinitely. There are a few operating systems that take care of reconfiguring services when the client moves to a new network(e.g. based on mechanisms like [RFC4436], [RFC4957] or [RFC6059]), but it's worth bearing in mind that a renew may not always result in the client taking up new configuration information that it receives.

In light of the above, when designing an option you should take into consideration the fact that your option may hold stale data that will only be updated at an arbitrary time in the future.

12. Multiple provisioning domains

In some cases there could be more than one DHCPv6 server on a link, with each providing a different set of parameters. One notable example of such a case is a home network with a connection to two independent ISPs.

The DHCPv6 protocol specification does not provide clear advice on how to handle multiple provisioning sources. Although [RFC3315] states that a client that receives more than one ADVERTISE message, may respond to one or more of them, such capability has not been observed in existing implementations. Existing clients will pick one server and will continue configuration process with that server, ignoring all other servers.

In addition, a node that acts as a DHCPv6 client may be connected to more than one physical network. In this case, it will in most cases operate a separate DHCP client state machine on each interface, acquiring different, possibly conflicting information through each. This information will not be acquired in any synchronized way.

Existing nodes cannot be assumed to systematically segregate configuration information on the basis of its source; as a result, it is quite possible that a node may receive an FQDN on one network interface, but do the DNS resolution on a different network interface, using different DNS servers. As a consequence, DNS resolution done by the DHCP server is more likely to behave predictably than DNS resolution done on a multi-interface or multi-homed client.

This is a generic DHCP protocol issue and should not be dealt within each option separately. This issue is better dealt with using a protocol-level solution and fixing this problem should not be attempted on a per option basis. Work is ongoing in the IETF to provide a systematic solution to this problem.

13. Chartering Requirements and Advice for Responsible Area Directors

Adding a simple DHCP option is straightforward, and generally something that any working group can do, perhaps with some help from designated DHCP experts. However, when new fragment types need to be devised, this requires the attention of DHCP experts, and should not be done in a working group that doesn't have a quorum of such experts. This is true whether the new fragment type has the same structure as an existing fragment type but has different semantics, or the new format has a new structure.

Responsible Area Directors for working groups that wish to add a work item to a working group charter to define a new DHCP option should get clarity from the working group as to whether the new option will require a new fragment type or new semantics, or whether it is a simple DHCP option that fits existing definitions.

If a working group needs a new fragment type, it is preferable to see if another working group exists whose members already have sufficient expertise to evaluate the new work. If such a working group is available, the work should be chartered in that working group instead. If there is no other working group with DHCP expertise that can define the new fragment type, the responsible AD should seek help from known DHCP experts within the IETF to provide advice and frequent early review as the original working group defines the new fragment type.

In either case, the new option should be defined in a separate document, and the work should focus on defining a new format that generalizes well and can be reused, rather than a single-use fragment type. The working group that needs the new fragment type can define their new option referencing the new fragment type document, and the work can generally be done in parallel, avoiding unnecessary delays. Having the definition in its own document will foster reuse of the new fragment type.

The responsible AD should work with all relevant working group chairs and DHCP experts to ensure that the new fragment type document has in fact been carefully reviewed by the experts and appears satisfactory.

Responsible area directors for working groups that are considering defining options that actually update the DHCP protocol, as opposed to simple options, should go through a process similar to that described above when trying to determine where to do the work. Under no circumstances should a working group be given a charter deliverable to define a new DHCP option, and then on the basis of that charter item actually make updates to the DHCP protocol.

14. Considerations for Creating New Formats

When defining new options, one specific consideration to evaluate is whether or not options of a similar format would need to have multiple or single values encoded (whatever differs from the current option), and how that might be accomplished in a similar format.

When defining a new option, it is best to synthesize the option format using fragment types already in use. However, in some cases there may be no fragment type that accomplishes the intended purpose.

The matter of size considerations and option order are further discussed in Section 15 and Section 17.

15. Option Size

DHCPv6 [RFC3315] allows for packet sizes up to 64KB. First, through its use of link-local addresses, it avoids many of the deployment problems that plague DHCPv4, and is actually an UDP over IPv6 based protocol (compared to DHCPv4, which is mostly UDP over IPv4 protocol, but with layer 2 hacks). Second, RFC 3315 explicitly refers readers to RFC 2460 Section 5, which describes an MTU of 1280 octets and a minimum fragment reassembly of 1500 octets. It's feasible to suggest that DHCPv6 is capable of having larger options deployed over it, and at least no common upper limit is yet known to have been encoded by its implementors. It is not really possible to describe a fixed limit that cleanly divides workable option sizes from those that are too big.

It is advantageous to prefer option formats which contain the desired information in the smallest form factor that satisfies the requirements. Common sense still applies here. It is better to split distinct values into separate octets rather than propose overly complex bit shifting operations to save several bits (or even an octet or two) that would be padded to the next octet boundary anyway.

DHCPv6 does allow for multiple instances of a given option, and they are treated as distinct values following the defined format, however this feature is generally preferred to be restricted to protocol class features (such as the IA_* series of options). In such cases, it is better to define an option as an array if it is possible. It is recommended to clarify (with normative language) whether a given DHCPv6 option may appear once or multiple times. The default assumption is only once.

In general, if a lot of data needs to be configured (for example, some option lengths are quite large), DHCPv6 may not be the best choice to deliver such configuration information and SHOULD simply be

used to deliver a URI that specifies where to obtain the actual configuration information.

16. Singleton options

Although [RFC3315] states that each option type MAY appear more than once, the original idea was that multiple instances are reserved for stateful options, like IA_NA or IA_PD. For most other options it is usually expected that they will appear at most once. Such options are called singleton options. Sadly, RFCs have often failed to clearly specify whether a given option can appear more than once or not.

Documents that define new options SHOULD state whether these options are singletons or not. Unless otherwise specified, newly defined options are considered to be singletons. If multiple instances are allowed, the document MUST explain how to use them. Care should be taken to not assume the they will be processed in the order they appear in the message. See Section 17 for more details.

When deciding whether a single or multiple option instances are allowed in a message, take into consideration how the content of the option will be used. Depending on the service being configured it may or may not make sense to have multiple values configured. If multiple values make sense, it is better to explicitly allow that by using option format that allows multiple values within one option instance.

Allowing multiple option instances often leads to confusion. Consider the following example. Basic DS-Lite architecture assumes that the B4 element (DHCPv6 client) will receive AFTR option and establish a single tunnel to configured tunnel termination point (AFTR). During standardization process of [RFC6334] there was a discussion whether multiple instances of DS-Lite tunnel option should be allowed. This created an unfounded expectation that the clients receiving multiple instances of the option will somehow know when one tunnel endpoint goes off-line and do some sort of failover between other values provided in other instances of the AFTR option. Others assumed that if there are multiple options, the client will somehow do a load balancing between provided tunnel endpoints. Neither failover nor load balancing was defined for DS-Lite architecture, so it caused confusion. It was eventually decided to allow only one instance of the AFTR option.

17. Option Order

Option order, either the order among many DHCPv6 options or the order of multiple instances of the same option, SHOULD NOT be significant. New documents MUST NOT assume any specific option processing order.

As there is no explicit order for multiple instance of the same option, an option definition SHOULD instead restrict ordering by using a single option that contains ordered fields.

As [RFC3315] does not impose option order, some implementations use hash tables to store received options (which is a conformant behavior). Depending on the hash implementation, the processing order is almost always different then the order in which options appeared in the packet on wire.

18. Relay Options

In DHCPv4, all relay options are organized as sub-options within DHCP Relay Agent Information Option[RFC3046]. And an independent number space called "DHCP Relay Agent Sub-options" is maintained by IANA. Different from DHCPv4, in DHCPv6, Relay options are defined in the same way as client/server options, and they too use the same number space as client/server options. Future DHCPv6 Relay options MUST be allocated from this single DHCPv6 Option number space.

E.g. the Relay-Supplied Options Option [RFC6422] may also contain some DHCPv6 options as permitted, such as the EAP Re-authentication Protocol (ERP) Local Domain Name DHCPv6 Option [RFC6440].

19. Clients Request their Options

The DHCPv6 Option Request Option (OPTION_ORO) [RFC3315], is an option that serves two purposes - to inform the server what options the client supports and to inform what options the client is willing to consume.

For some options, such as the options required for the functioning of the DHCPv6 protocol itself, it doesn't make sense to require that they be explicitly requested using the Option Request Option. In all other cases, it is prudent to assume that any new option must be present on the relevant option request list if the client desires to receive it.

It is tempting to add text that requires the client to include a new option in Option Request Option list, similar to this text: "Clients MUST place the foo option code on the Option Request Option list, clients MAY include option foo in their packets as hints for the

server as values the desire, and servers MUST include option foo when the client requested it (and the server has been so configured)". Such text is discouraged as there are several issues with it. First, it assumes that client implementation that supports a given option will always want to use it. This is not true. The second and more important reason is that such text essentially duplicates mechanism already defined in [RFC3315]. It is better to simply refer to the existing mechanism rather than define it again. See Section 21 for proposed examples on how to do that.

Creators of DHCPv6 options cannot not assume special ordering of options either as they appear in the option request option, or as they appear within the packet. Although it is reasonable to expect that options will be processed in the order they appear in ORO, server software is not required to sort DHCPv6 options into the same order in reply messages.

It should also be noted that options values are never aligned within the DHCP packet, even the option code and option length may appear on odd byte boundaries.

20. Transition Technologies

Transition from IPv4 to IPv6 is progressing. Many transition technologies are proposed to speed it up. As a natural consequence there are also DHCP options proposed to provision those proposals. The inevitable question is whether the required parameters should be delivered over DHCPv4 or DHCPv6. Authors often don't give much thought about it and simply pick DHCPv6 without realizing the consequences. IPv6 is expected to stay with us for many decades, and so is DHCPv6. There is no mechanism available to deprecate an option in DHCPv6, so any options defined will stay with us as long as DHCPv6 protocol itself. It seems likely that such options defined to transition from IPv4 will outlive IPv4 by many decades. From that perspective it is better to implement provisioning of the transition technologies in DHCPv4, which will be obsoleted together with IPv4.

When the network infrastructure becomes IPv6-only, the support for IPv4-only nodes may still be needed. In such a scenario, a mechanism for providing IPv4 configuration information over IPv6-only networks such as [I-D.ietf-dhc-v4configuration] may be needed.

21. Recommended sections in the new document

There are three major entities in DHCPv6 protocol: server, relay agent, and client. It is very helpful for implementers to include separate sections that describe operation for those three major entities. Even when a given entity does not participate, it is

useful to have a very short section stating that it must not send a given option and must ignore it when received.

There is also a separate entity called requestor, which is a special client-like type that participates in leasequery protocol [RFC5007] and [RFC5460]. A similar section for the requestor is not required, unless the new option has anything to do with requestor (or it is likely that the reader may think that is has). It should be noted that while in the majority of deployments, requestor is co-located with relay agent, those are two separate entities from the protocol perspective and they may be used separately. There are stand-alone requestor implementations available.

The following sections include proposed text for such sections. That text is not required to appear, but it is appropriate in most cases. Additional or modified text specific to a given option is often required.

Although requestor is somewhat uncommon functionality, its existence should be noted, especially when allowing or disallowing options to appear in certain message or being sent by certain entities. Additional message types may appear in the future, besides types defined in [RFC3315]. Therefore authors are encouraged to familiarize themselves with a list of currently defined DHCPv6 messages available on IANA website [iana].

Typically new options are requested by clients and assigned by the server, so there is no specific relay behavior. Nevertheless it is good to include a section for relay agent behavior and simply state that there are no additional requirements for relays. The same applies for client behavior if the options are to be exchanged between relay and server.

Sections that contain option definitions MUST include formal verification procedure. Often it is very simple, e.g. option that conveys IPv6 address must be exactly 16 bytes long, but sometimes the rules are more complex. It is recommeded to refer to existing documents (e.g. section 8 of RFC3315 for domain name encoding) rather than trying to repeat such rules.

21.1. DHCPv6 Client Behavior Text

Clients MAY request option foo, as defined in [RFC3315], sections 17.1.1, 18.1.1, 18.1.3, 18.1.4, 18.1.5 and 22.7. As a convenience to the reader, we mention here that the client includes requested option codes in Option Request Option.

Optional text (if client's hints make sense): Client also MAY include option foo in its SOLICIT, REQUEST, RENEW, REBIND and INFORMATION-REQUEST messages as a hint for the server regarding preferred option values.

Optional text (if the option contains FQDN): If the client requests an option that conveys an FQDN, it is expected that the contents of that option will be resolved using DNS. Hence the following text may be useful: Clients that request option foo SHOULD also request option OPTION_DNS_SERVERS specified in [RFC3646].

Clients MUST discard option foo if it is invalid (i.e. did not pass validation steps defined in Section X.Y).

Optional text (if option foo in expected to be exchanged between relays and servers): Option foo is exchanged between relays and servers only. Clients are not aware of the usage of option foo. Clients MUST ignore received option foo.

21.2. DHCPv6 Server Behavior Text

Sections 17.2.2 and 18.2 of [RFC3315] govern server operation in regards to option assignment. As a convenience to the reader, we mention here that the server will send option foo only if configured with specific values for foo and the client requested it.

Optional text: Option foo is a singleton. Servers MUST NOT send more than one instance of foo option.

Optional text (if server is never supposed to receive option foo): Servers MUST ignore incoming foo option.

21.3. DHCPv6 Relay Agent Behavior Text

It's never appropriate for a relay agent to add options to a message heading toward the client, and relay agents don't actually construct Relay-Reply messages anyway.

Optional text (if foo option is exchanged between clients and server or between requestors and servers): There are no additional requirements for relays.

Optional text (if relays are expected to insert or consume option foo): Relay agents MAY include option foo in a Relay-Forw when forwarding packets from clients to the servers.

22. Should the new document update existing RFCs?

Authors often ask themselves a question whether their proposal updates exist RFCs, especially 3315. In April 2013 there were about 80 options defined. Had all documents that defined them also updated RFC3315, comprehension of such a document set would be extremely difficult. It should be noted that "extends" and "updates" are two very different verbs. If a new draft defines a new option that clients request and servers provide, it merely extends current standards, so "updates 3315" is not required in the new document header. On the other hand, if a new document replaces or modifies existing behavior, includes clarifications or other corrections, it should be noted that it updates the other document. For example, [RFC6644] clearly updates [RFC3315] as it replaces existing with new text.

If in doubt, authors should try to answer a question whether implementor reading the base RFC alone (without reading the new draft) would be able to properly implement the software. If the base RFC is sufficient, that the new draft most probably does not update the base RFC. On the other hand, if reading your draft is necessary to properly implement the base RFC, then the new draft most likely updates the base RFC.

23. Security Considerations

DHCPv6 does have an Authentication mechanism ([RFC3315]) that makes it possible for DHCPv6 software to discriminate between authentic endpoints and man-in-the-middle. Other authentication mechanisms may optionally be deployed. Sadly, as of late 2013, the authentication in DHCPv6 is rarely used and support for it is not common in existing implementations. Some specific deployment types make it mandatory (or parts of thereof, e.g. DOCSIS3.0 compatible cable modems require reconfigure-key support), so in certain cases specific authentication aspects can be relied upon. That is not true in the generic case, though.

So, while creating a new option, it is prudent to assume that the DHCPv6 packet contents are always transmitted in the clear, and actual production use of the software will probably be vulnerable at least to man-in-the-middle attacks from within the network, even where the network itself is protected from external attacks by firewalls. In particular, some DHCPv6 message exchanges are transmitted to multicast addresses that are likely broadcast anyway.

If an option is of a specific fixed length, it is useful to remind the implementer of the option data's full length. This is easily done by declaring the specific value of the 'length' tag of the

option. This helps to gently remind implementers to validate option length before digesting them into likewise fixed length regions of memory or stack.

If an option may be of variable size (such as having indeterminate length fields, such as domain names or text strings), it is advisable to explicitly remind the implementor to be aware of the potential for long options. Either define a reasonable upper limit (and suggest validating it), or explicitly remind the implementor that an option may be exceptionally long (to be prepared to handle errors rather than truncate values).

For some option contents, out of bound values may be used to breach security. An IP address field might be made to carry a loopback address, or local multicast address, and depending on the protocol this may lead to undesirable results. A domain name field may be filled with contrived contents that exceed the limitations placed upon domain name formatting - as this value is possibly delivered to "internal configuration" records of the system, it may be implicitly trusted without being validated.

Authors of drafts defining new DHCP options are therefore strongly advised to explicitly define validation measures that recipients of such options are required to do before processing such options. However, validation measures already defined by RFC3315 or other specifications referenced by the new option document are redundant, and can introduce errors, so authors are equally strongly advised to refer to the base specification for any such validation language rather than copying it into the new specification.

Also see Section 24.

24. Privacy considerations

As discussed in Section 23 the DHCPv6 packets are typically transmitted in the clear, so they are susceptible to eavesdropping. This should be considered when defining options that may convey personally identifying information (PII) or any other type of sensitive data.

If the transmission of sensitive or confidential content is required, it is still possible to secure communication between relay agents and servers. Relay agents and servers implementing this specification MUST support the use of IPsec Encapsulating Security Payload (ESP) with encryption in transport mode, according to Section 3.1.1 of [RFC4303] and Section 21.1 of [RFC3315]. Sadly, this requirement is almost universally ingored in real deployments. Even if the

communication path between relay agents and server is secured, the path between clients and relay agents or server is not.

Unless underlying transmission technology provides secure transmission channel, the DHCPv6 options SHOULD NOT include PII or other sensitive information. If there are special circumstances that warrant sending such information over unsecured DHCPv6, the dangers MUST be clearly discussed in security considerations.

25. IANA Considerations

This document has no actions for IANA.

26. Acknowledgements

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