

CoRE
Internet-Draft
Intended status: Standards Track
Expires: May 4, 2017

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October 31, 2016

CoRE Resource Directory
draft-ietf-core-resource-directory-09

Abstract

In many M2M applications, direct discovery of resources is not practical due to sleeping nodes, disperse networks, or networks where multicast traffic is inefficient. These problems can be solved by employing an entity called a Resource Directory (RD), which hosts descriptions of resources held on other servers, allowing lookups to be performed for those resources. This document specifies the web interfaces that a Resource Directory supports in order for web servers to discover the RD and to register, maintain, lookup and remove resource descriptions. Furthermore, new link attributes useful in conjunction with an RD are defined.

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[1.](#) Introduction

The work on Constrained RESTful Environments (CoRE) aims at realizing the REST architecture in a suitable form for the most constrained nodes (e.g., 8-bit microcontrollers with limited RAM and ROM) and networks (e.g. 6LoWPAN). CoRE is aimed at machine-to-machine (M2M) applications such as smart energy and building automation.

The discovery of resources offered by a constrained server is very important in machine-to-machine applications where there are no humans in the loop and static interfaces result in fragility. The discovery of resources provided by an HTTP Web Server is typically called Web Linking [[RFC5988](#)]. The use of Web Linking for the description and discovery of resources hosted by constrained web servers is specified by the CoRE Link Format [[RFC6690](#)]. However, [[RFC6690](#)] only describes how to discover resources from the web server that hosts them by requesting `"/.well-known/core"`. In many M2M scenarios, direct discovery of resources is not practical due to sleeping nodes, disperse networks, or networks where multicast

traffic is inefficient. These problems can be solved by employing an entity called a Resource Directory (RD), which hosts descriptions of resources held on other servers, allowing lookups to be performed for those resources.

This document specifies the web interfaces that a Resource Directory supports in order for web servers to discover the RD and to register, maintain, lookup and remove resource descriptions. Furthermore, new link attributes useful in conjunction with a Resource Directory are defined. Although the examples in this document show the use of these interfaces with CoAP [[RFC7252](#)], they can be applied in an equivalent manner to HTTP [[RFC7230](#)].

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [[RFC2119](#)]. The term "byte" is used in its now customary sense as a synonym for "octet".

This specification requires readers to be familiar with all the terms and concepts that are discussed in [[RFC5988](#)] and [[RFC6690](#)]. Readers should also be familiar with the terms and concepts discussed in [[RFC7252](#)]. To describe the REST interfaces defined in this specification, the URI Template format is used [[RFC6570](#)].

This specification makes use of the following additional terminology:

Resource Directory

A web entity that stores information about web resources and implements the REST interfaces defined in this specification for registration and lookup of those resources.

Domain

In the context of a Resource Directory, a domain is a logical grouping of endpoints. This specification assumes that the list of Domains supported by an RD is pre-configured by that RD. When a domain is exported to DNS, the domain value equates to the DNS domain name.

Group

In the context of a Resource Directory, a group is a logical grouping of endpoints for the purpose of group communications. All groups within a domain are unique.

Endpoint

Endpoint (EP) is a term used to describe a web server or client in [RFC7252]. In the context of this specification an endpoint is used to describe a web server that registers resources to the Resource Directory. An endpoint is identified by its endpoint name, which is included during registration, and is unique within the associated domain of the registration.

Commissioning Tool

Commissioning Tool (CT) is a device that assists during the installation of the network by assigning values to parameters, naming endpoints and groups, or adapting the installation to the needs of the applications.

RDAO

Resource Directory Address Option.

3. Architecture and Use Cases

The resource directory architecture is illustrated in Figure 1. A Resource Directory (RD) is used as a repository for Web Links [RFC5988] about resources hosted on other web servers, which are called endpoints (EP). An endpoint is a web server associated with a scheme, IP address and port (called Context), thus a physical node may host one or more endpoints. The RD implements a set of REST interfaces for endpoints to register and maintain sets of Web Links (called resource directory entries), and for clients to lookup resources from the RD or maintain groups. Endpoints themselves can also act as clients. An RD can be logically segmented by the use of Domains. The domain an endpoint is associated with can be defined by the RD or configured by an outside entity. This information hierarchy is shown in Figure 2.

Endpoints are assumed to proactively register and maintain resource directory entries on the RD, which are soft state and need to be periodically refreshed. An endpoint is provided with interfaces to register, update and remove a resource directory entry. Furthermore, a mechanism to discover an RD using the CoRE Link Format [RFC6690] is defined. It is also possible for an RD to proactively discover Web Links from endpoints and add them as resource directory entries. A lookup interface for discovering any of the Web Links held in the RD is provided using the CoRE Link Format.

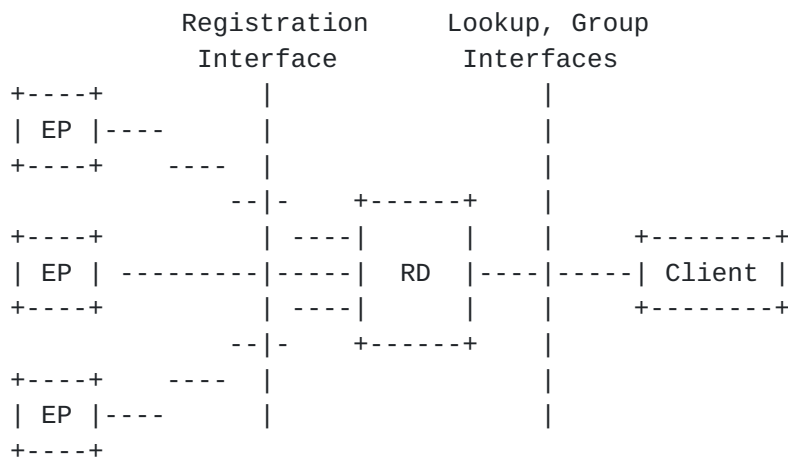


Figure 1: The resource directory architecture.

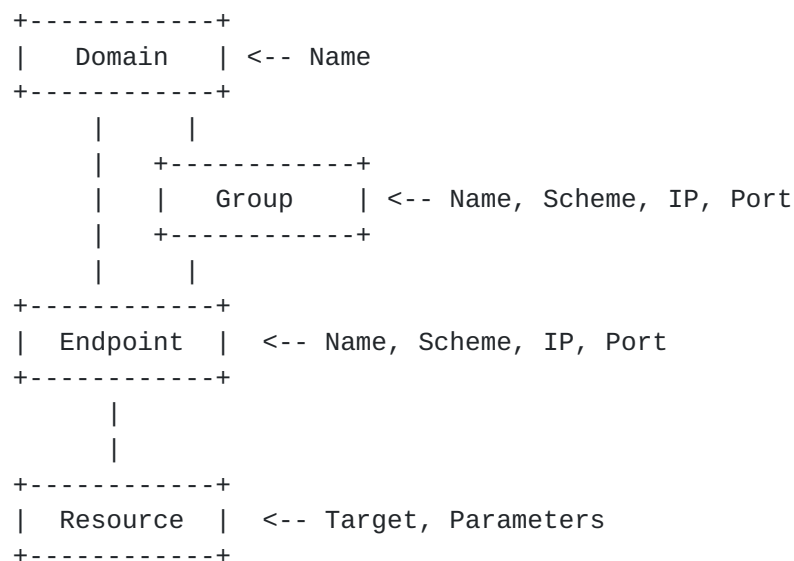


Figure 2: The resource directory information hierarchy.

3.1. Use Case: Cellular M2M

Over the last few years, mobile operators around the world have focused on development of M2M solutions in order to expand the business to the new type of users: machines. The machines are connected directly to a mobile network using an appropriate embedded air interface (GSM/GPRS, WCDMA, LTE) or via a gateway providing short and wide range wireless interfaces. From the system design point of view, the ambition is to design horizontal solutions that can enable utilization of machines in different applications depending on their current availability and capabilities as well as application

requirements, thus avoiding silo like solutions. One of the crucial enablers of such design is the ability to discover resources (machines -- endpoints) capable of providing required information at a given time or acting on instructions from the end users.

In a typical scenario, during a boot-up procedure (and periodically afterwards), the machines (endpoints) register with a Resource Directory (for example EPs installed on vehicles enabling tracking of their position for fleet management purposes and monitoring environment parameters) hosted by the mobile operator or somewhere else in the network, periodically a description of its own capabilities. Due to the usual network configuration of mobile networks, the EPs attached to the mobile network may not always be efficiently reachable. Therefore, a remote server is usually used to provide proxy access to the EPs. The address of each (proxy) endpoint on this server is included in the resource description stored in the RD. The users, for example mobile applications for environment monitoring, contact the RD, look up the endpoints capable of providing information about the environment using appropriate set of link parameters, obtain information on how to contact them (URLs of the proxy server) and then initiate interaction to obtain information that is finally processed, displayed on the screen and usually stored in a database. Similarly, fleet management systems provide the appropriate link parameters to the RD to look up for EPs deployed on the vehicles the application is responsible for.

3.2. Use Case: Home and Building Automation

Home and commercial building automation systems can benefit from the use of M2M web services. The discovery requirements of these applications are demanding. Home automation usually relies on run-time discovery to commission the system, whereas in building automation a combination of professional commissioning and run-time discovery is used. Both home and building automation involve peer-to-peer interactions between endpoints, and involve battery-powered sleeping devices.

The exporting of resource information to other discovery systems is also important in these automation applications. In home automation there is a need to interact with other consumer electronics, which may already support DNS-SD, and in building automation DNS-SD in combination with resource directories can cover multiple buildings.

3.3. Use Case: Link Catalogues

Resources may be shared through data brokers that have no knowledge beforehand of who is going to consume the data. Resource Directory can be used to hold links about resources and services hosted

anywhere to make them discoverable by a general class of applications.

For example, environmental and weather sensors that generate data for public consumption may provide the data to an intermediary server, or broker. Sensor data are published to the intermediary upon changes or at regular intervals. Descriptions of the sensors that resolve to links to sensor data may be published to a Resource Directory. Applications wishing to consume the data can use the Resource Directory lookup function set to discover and resolve links to the desired resources and endpoints. The Resource Directory service need not be coupled with the data intermediary service. Mapping of Resource Directories to data intermediaries may be many-to-many.

Metadata in web-link compatible representations are supplied by Resource Directories, which may be internally stored as triples, or relation/attribute pairs providing metadata about resource links. External catalogs that are represented in other formats may be converted to common web linking formats for storage and access by Resource Directories. Since it is common practice for these to be URN encoded, simple and lossless structural transforms should generally be sufficient to store external metadata in Resource Directories.

The additional features of Resource Directory allow domains to be defined to enable access to a particular set of resources from particular applications. This provides isolation and protection of sensitive data when needed. Resource groups may defined to allow batched reads from multiple resources.

4. Finding a Directory Server

Endpoints that want to contact a directory server can obtain candidate IP addresses for such servers in a number of ways.

In a 6LoWPAN, good candidates can be taken from:

- o specific static configuration (e.g., anycast addresses), if any,
- o the ABRO option of 6LoWPAN-ND [[RFC6775](#)],
- o other ND options that happen to point to servers (such as RDNSS),
- o DHCPv6 options that might be defined later.
- o The IPv6 Neighbor Discovery Resource Directory Address Option described in [Section 4.1](#)

In networks with more inexpensive use of multicast, the candidate IP address may be a well-known multicast address, i.e. directory servers are found by simply sending GET requests to that well-known multicast address (see [Section 6.2](#)).

As some of these sources are just (more or less educated) guesses, endpoints MUST make use of any error messages to very strictly rate-limit requests to candidate IP addresses that don't work out. For example, an ICMP Destination Unreachable message (and, in particular, the port unreachable code for this message) may indicate the lack of a CoAP server on the candidate host, or a CoAP error response code such as 4.05 "Method Not Allowed" may indicate unwillingness of a CoAP server to act as a directory server.

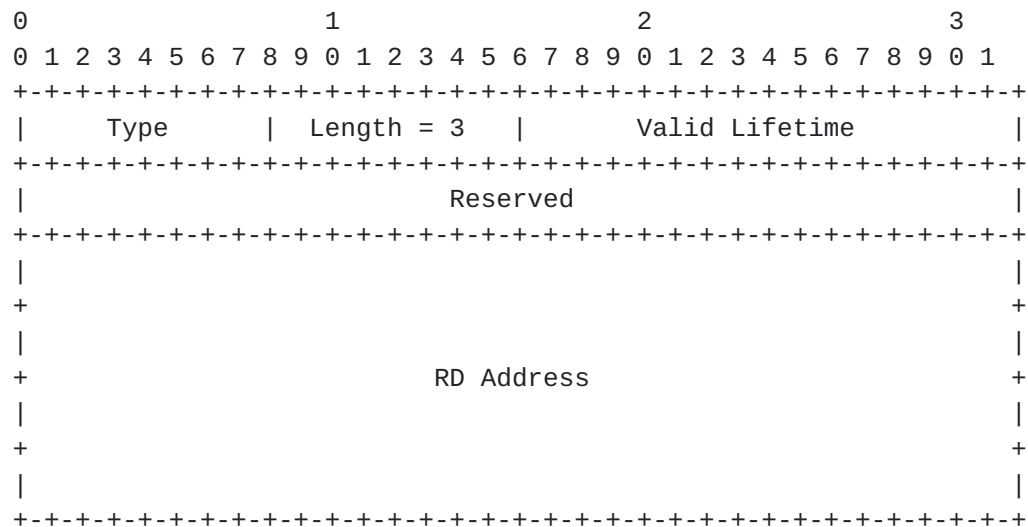
[4.1](#). Resource Directory Address Option (RDAO)

The Resource Directory Option (RDAO) using IPv6 neighbor Discovery (ND) carries information about the address of the Resource Directory (RD). This information is needed when endpoints cannot discover the Resource Directory with link-local multicast address because the endpoint and the RD are separated by a border Router (6LBR). In many circumstances the availability of DHCP cannot be guaranteed either during commissioning of the network. The presence and the use of the RD is essential during commissioning.

It is possible to send multiple RDAO options in one message, indicating as many resource directory addresses.

The lifetime 0x0 means that the RD address is invalid and to be removed.

The RDAO format is:



Fields:

Type:	38
Length:	8-bit unsigned integer. The length of the option in units of 8 bytes. Always 3.
Valid Lifetime:	16-bit unsigned integer. The length of time in units of 60 seconds (relative to the time the packet is received) that this set of border router information is valid. A value of all zero bits (0x0) assumes a default value of 10,000 (~one week).
Reserved:	This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.
RD Address:	IPv6 address of the RD.

Figure 3: Resource Directory Address Option

5. Simple Registration

Not all endpoints hosting resources are expected to know how to implement the Resource Directory Function Set (see [Section 6](#)) hence cannot register with a Resource Directory. Instead, simple endpoints can implement the generic Simple Directory Discovery approach described in this section. An RD implementing this specification MUST implement Simple Directory Discovery. However, there may be

security reasons why this form of directory discovery would be disabled.

This approach requires that the endpoint makes available the hosted resources that it wants to be discovered, as links on its `"/.well-known/core"` interface as specified in [[RFC6690](#)].

The endpoint then finds one or more addresses of the directory server as described in [Section 4](#).

An endpoint can send (a selection of) hosted resources to a directory server for publication as described in [Section 5.1](#).

The directory server integrates the information it received this way into its resource directory. It MAY make the information available to further directories, if it can ensure that a loop does not form. The protocol used between directories to ensure loop-free operation is outside the scope of this document.

[5.1](#). Simple publishing to Resource Directory Server

An endpoint that wants to make itself discoverable occasionally sends a POST request to the `"/.well-known/core"` URI of any candidate directory server that it finds. The body of the POST request is empty, which triggers the resource directory server to perform GET requests at the requesting server's default discovery URI to obtain the link-format payload to register.

The endpoint MAY include registration parameters in the POST request as per [Section 6.3](#).

The following example shows an endpoint using simple publishing, by simply sending an empty POST to a resource directory.


```
Req:(to RD server from [ff02::1])
POST coap://rd.example.com/.well-known/core?lt=6000
```

```
Content-Format: 40
```

```
payload:
```

```
(empty payload)
```

```
Res: 2.04 Changed
```

```
(later)
```

```
Req: (from RD server to [ff02::1])
GET coap://[ff02::1]/.well-known/core
```

```
Accept: 40
```

```
Res: 2.05 Content
```

```
payload:
```

```
</sen/temp>
```

5.2. Third-party registration

For some applications, even Simple Directory Discovery may be too taxing for certain very constrained devices, in particular if the security requirements become too onerous.

In a controlled environment (e.g. building control), the Resource Directory can be filled by a third device, called a commissioning tool. The commissioning tool can fill the Resource Directory from a database or other means. For that purpose the scheme, IP address and port of the registered device is indicated in the Context parameter of the registration described in [Section 6.3](#).

6. Resource Directory Function Set

This section defines the REST interfaces between an RD and endpoints, which is called the Resource Directory Function Set. Although the examples throughout this section assume the use of CoAP [[RFC7252](#)], these REST interfaces can also be realized using HTTP [[RFC7230](#)]. In all definitions in this section, both CoAP response codes (with dot notation) and HTTP response codes (without dot notation) are shown. An RD implementing this specification MUST support the discovery, registration, update, lookup, and removal interfaces defined in this section.

Resource directory entries are designed to be easily exported to other discovery mechanisms such as DNS-SD. For that reason, parameters that would meaningfully be mapped to DNS SHOULD be limited to a maximum length of 63 bytes.

6.1. Content Formats

Resource Directory implementations using this specification MUST support the application/link-format content format (ct=40).

Resource Directories implementing this specification MAY support additional content formats.

Any additional content format supported by a Resource Directory implementing this specification MUST have an equivalent serialization in the application/link-format content format.

6.2. Discovery

Before an endpoint can make use of an RD, it must first know the RD's address and port, and the path of its RD Function Set. There can be several mechanisms for discovering the RD including assuming a default location (e.g. on an Edge Router in a LoWPAN), by assigning an anycast address to the RD, using DHCP, or by discovering the RD using the CoRE Link Format (see also [Section 4](#)). This section defines discovery of the RD using the well-known interface of the CoRE Link Format [[RFC6690](#)] as the required mechanism. It is however expected that RDs will also be discoverable via other methods depending on the deployment.

Discovery of the RD function set is performed by sending either a multicast or unicast GET request to `"/.well-known/core"` and including a Resource Type (rt) parameter [[RFC6690](#)] with the value `"core.rd"` in the query string. Likewise, a Resource Type parameter value of `"core.rd-lookup"` is used to discover the RD Lookup Function Set. Upon success, the response will contain a payload with a link format entry for each RD discovered, with the URL indicating the root resource of the RD. When performing multicast discovery, the multicast IP address used will depend on the scope required and the multicast capabilities of the network.

A Resource Directory MAY provide hints about the content-formats it supports in the links it exposes or registers, using the `"ct"` link attribute, as shown in the example below. Clients MAY use these hints to select alternate content-formats for interaction with the Resource Directory.

HTTP does not support multicast and consequently only unicast discovery can be supported using HTTP. Links to Resource Directories MAY be registered in other Resource Directories, and well-known entry points SHOULD be provided to enable the bootstrapping of unicast discovery.

An RD implementation of this specification MUST support query filtering for the `rt` parameter as defined in [[RFC6690](#)].

The discovery request interface is specified as follows:

Interaction: EP -> RD

Method: GET

URI Template: `/.well-known/core{?rt}`

URI Template Variables:

`rt` := Resource Type (optional). MAY contain one or more of the values "core.rd", "core.rd-lookup", "core.rd-group" or "core.rd*"

Content-Format: application/link-format (if any)

Content-Format: application/link-format+json (if any)

Content-Format: application/link-format+cbor (if any)

The following response codes are defined for this interface:

Success: 2.05 "Content" with an application/link-format, application/link-format+json, or application/link-format+cbor payload containing one or more matching entries for the RD resource.

Failure: 4.04 "Not Found" is returned in case no matching entry is found for a unicast request.

Failure: 4.00 "Bad Request" is returned in case of a malformed request for a unicast request.

Failure: No error response to a multicast request.

HTTP support : YES (Unicast only)

The following example shows an endpoint discovering an RD using this interface, thus learning that the base RD resource is, in this

example, at /rd and that the content_format delivered by the server hosting the resource is application.xml (ct=40). Note that it is up to the RD to choose its base RD resource, although diagnostics and debugging is facilitated by using the base paths specified here where possible.

```
Req: GET coap://[ff02::1]/.well-known/core?rt=core.rd*
```

```
Res: 2.05 Content
```

```
</rd>;rt="core.rd";ct=40,  
</rd-lookup>;rt="core.rd-lookup";ct=40,  
</rd-group>;rt="core.rd-group";ct=40
```

The following example shows the way of indicating that a client may request alternate content-formats. The Content-Format code attribute "ct" MAY include a space-separated sequence of Content-Format codes as specified in [Section 7.2.1 of \[RFC7252\]](#), indicating that multiple content-formats are available. The example below shows the required Content-Format 40 (application/link-format) indicated as well as a more application-specific content format (picked as 65225 in this example; this is in the experimental space, not an assigned value). The base RD resource values /rd, /rd-lookup, and /rd-group are example values.

```
Req: GET coap://[ff02::1]/.well-known/core?rt=core.rd*
```

```
Res: 2.05 Content
```

```
</rd>;rt="core.rd";ct="40 65225",  
</rd-lookup>;rt="core.rd-lookup";ct="40 65225",  
</rd-group>;rt="core.rd-group";ct="40 65225"
```

6.3. Registration

After discovering the location of an RD Function Set, an endpoint MAY register its resources using the registration interface. This interface accepts a POST from an endpoint containing the list of resources to be added to the directory as the message payload in the CoRE Link Format [\[RFC6690\]](#), JSON CoRE Link Format (application/link-format+json), or CBOR CoRE Link Format (application/link-format+cbor) [\[I-D.ietf-core-links-json\]](#), along with query string parameters indicating the name of the endpoint, its domain and the lifetime of the registration. All parameters except the endpoint name are optional. It is expected that other specifications will define further parameters (see [Section 12.4](#)). The RD then creates a new resource or updates an existing resource in the RD and returns its location. An endpoint MUST use that location when refreshing registrations using this interface. Endpoint resources in the RD are kept active for the period indicated by the lifetime parameter. The

endpoint is responsible for refreshing the entry within this period using either the registration or update interface. The registration interface **MUST** be implemented to be idempotent, so that registering twice with the same endpoint parameter does not create multiple RD entries. A new registration may be created at any time to supersede an existing registration, replacing the registration parameters and links.

The registration request interface is specified as follows:

Interaction: EP -> RD

Method: POST

URI Template: `/[+rd]{?ep,d,et,lt,con}`

URI Template Variables:

`rd` := RD Function Set path (mandatory). This is the path of the RD Function Set, as obtained from discovery. The value "rd" is recommended for this variable.

`ep` := Endpoint name (mandatory). The endpoint name is an identifier that **MUST** be unique within a domain. The maximum length of this parameter is 63 bytes.

`d` := Domain (optional). The domain to which this endpoint belongs. The maximum length of this parameter is 63 bytes. When this parameter is elided, the RD **MAY** associate the endpoint with a configured default domain. The domain value is needed to export the endpoint to DNS-SD (see [Section 10](#)).

`et` := Endpoint Type (optional). The semantic type of the endpoint. This parameter **SHOULD** be less than 63 bytes.

`lt` := Lifetime (optional). Lifetime of the registration in seconds. Range of 60-4294967295. If no lifetime is included, a default value of 86400 (24 hours) **SHOULD** be assumed.

`con` := Context (optional). This parameter sets the scheme, address and port at which this server is available in the form `scheme://host:port`. In the absence of this parameter the scheme of the protocol, source IP address and source port of the register request are assumed. This parameter is mandatory when the directory is filled by a third party such as an commissioning tool.

Content-Format: application/link-format

Content-Format: application/link-format+json

Content-Format: application/link-format+cbor

The following response codes are defined for this interface:

Success: 2.01 "Created" or 201 "Created". The Location header MUST be included with the new resource entry for the endpoint. This Location MUST be a stable identifier generated by the RD as it is used for all subsequent operations on this registration. The resource returned in the Location is for the purpose of updating the lifetime of the registration and for maintaining the content of the registered links, including updating and deleting links.

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following example shows an endpoint with the name "node1" registering two resources to an RD using this interface. The location "/rd" is an example value of an RD base location.

Req: POST coap://rd.example.com/rd?ep=node1

Content-Format: 40

Payload:

```
</sensors/temp>;ct=41;rt="temperature-c";if="sensor",  
</sensors/light>;ct=41;rt="light-lux";if="sensor"
```

Res: 2.01 Created

Location: /rd/4521

Req: POST /rd?ep=node1 HTTP/1.1

Host : example.com

Content-Type: application/link-format

Payload:

```
</sensors/temp>;ct=41;rt="temperature-c";if="sensor",  
</sensors/light>;ct=41;rt="light-lux";if="sensor"
```

Res: 201 Created

Location: /rd/4521

6.4. Registration Update

The update interface is used by an endpoint to refresh or update its registration with an RD. To use the interface, the endpoint sends a POST request to the resource returned in the Location option in the response to the first registration.

An update MAY update the lifetime or context registration parameters "lt", "con" as in [Section 6.3](#)) if they have changed since the last registration or update. Parameters that have not changed SHOULD NOT be included in an update. Adding parameters that have not changed increases the size of the message but does not have any other implications. Parameters MUST be included as query parameters in an update operation as in [Section 6.3](#).

Upon receiving an update request, an RD MUST reset the timeout for that endpoint and update the scheme, IP address and port of the endpoint, using the source address of the update, or the context ("con") parameter if present. If the lifetime parameter "lt" is included in the received update request, the RD MUST update the lifetime of the registration and set the timeout equal to the new lifetime.

An update MAY optionally add or replace links for the endpoint by including those links in the payload of the update as a CoRE Link Format document. A link is replaced only if both the target URI and relation type match.

In addition to the use of POST, as described in this section, there is an alternate way to add, replace, and delete links using PATCH as described in [Section 6.7](#).

The update registration request interface is specified as follows:

Interaction: EP -> RD

Method: POST

URI Template: `/[+location]{?lt,con}`

URI Template Variables:

location := This is the Location path returned by the RD as a result of a successful earlier registration.

lt := Lifetime (optional). Lifetime of the registration in seconds. Range of 60-4294967295. If no lifetime is included, a default value of 86400 (24 hours) SHOULD be assumed.

con := Context (optional). This parameter sets the scheme, address and port at which this server is available in the form scheme://host:port. Optional. In the absence of this parameter the scheme of the protocol, source IP address and source port used to register are assumed. This parameter is compulsory when the directory is filled by a third party such as a commissioning tool.

Content-Format: application/link-format (mandatory)

Content-Format: application/link-format+json (optional)

Content-Format: application/link-format+cbor (optional)

The following response codes are defined for this interface:

Success: 2.04 "Changed" or 204 "No Content" if the update was successfully processed.

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 4.04 "Not Found" or 404 "Not Found". Registration does not exist (e.g. may have expired).

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following example shows an endpoint updating its registration at an RD using this interface with the example location value: /rd/4521.

Req: POST /rd/4521

Res: 2.04 Changed

The following example shows an endpoint updating its registration with a new lifetime and context, changing an existing link, and adding a new link using this interface with the example location value /rd/4521. With the initial registration the client set the following values:

- o lifetime (lt)=500
- o context (con)=coap://local-proxy-old.example.com:5683
- o resource= </sensors/temp>;ct=41;rt="foobar";if="sensor"


```
Req: POST /rd/4521?lt=600&con="coap://local-proxy.example.com:5683"
Content-Format: 40
Payload:
</sensors/temp>;ct=41;rt="temperature-f";if="sensor",
</sensors/door>;ct=41;rt="door";if="sensor"

Res: 2.04 Changed
```

[6.5.](#) Registration Removal

Although RD entries have soft state and will eventually timeout after their lifetime, an endpoint SHOULD explicitly remove its entry from the RD if it knows it will no longer be available (for example on shut-down). This is accomplished using a removal interface on the RD by performing a DELETE on the endpoint resource.

The removal request interface is specified as follows:

Interaction: EP -> RD

Method: DELETE

URI Template: /{+location}

URI Template Variables:

location := This is the Location path returned by the RD as a result of a successful earlier registration.

The following responses codes are defined for this interface:

Success: 2.02 "Deleted" or 204 "No Content" upon successful deletion

Failure: 4.00 "Bad Request" or 400 "Bad request". Malformed request.

Failure: 4.04 "Not Found" or 404 "Not Found". Registration does not exist (e.g. may have expired).

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following examples shows successful removal of the endpoint from the RD with example location value /rd/4521.

Req: DELETE /rd/4521

Res: 2.02 Deleted

6.6. Read Endpoint Links

Some endpoints may wish to manage their links as a collection, and may need to read the current set of links in order to determine link maintenance operations.

One or more links MAY be selected by using query filtering as specified in [\[RFC6690\] Section 4.1](#)

The read request interface is specified as follows:

Interaction: EP -> RD

Method: GET

URI Template: `/[+location]{?href,rel,rt,if,ct}`

URI Template Variables:

location := This is the Location path returned by the RD as a result of a successful earlier registration.

href,rel,rt,if,ct := link relations and attributes specified in the query in order to select particular links based on their relations and attributes. "href" denotes the URI target of the link. See [\[RFC6690\]](#) Sec. 4.1

The following responses codes are defined for this interface:

Success: 2.05 "Content" or 200 "OK" upon success with an "application/link-format", "application/link-format+cbor", or "application/link-format+json" payload.

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 4.04 "Not Found" or 404 "Not Found". Registration does not exist (e.g. may have expired).

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following examples show successful read of the endpoint links from the RD, with example location value /rd/4521.

Req: GET /rd/4521

Res: 2.01 Content

Payload:

```
</sensors/temp>;ct=41;rt="temperature-c";if="sensor",  
</sensors/light>;ct=41;rt="light-lux";if="sensor"
```

6.7. Update Endpoint Links

[This section will be removed before or as a result of a working-group last-call if the PATCH methods do not achieve the same level of consensus as the present document.]

A PATCH update adds, removes or changes links for the endpoint by including link update information in the payload of the update as a merge-patch+json format [[RFC7396](#)] document.

One or more links are selected for update by using query filtering as specified in [[RFC6690](#)] [Section 4.1](#)

The query filter selects the links to be modified or deleted, by matching the query parameter values to the values of the link attributes.

When the query parameters are not present in the request, the payload specifies links to be added to the target document. When the query parameters are present, the attribute names and values in the query parameters select one or more links on which to apply the PATCH operation.

If an attribute name specified in the PATCH document exists in any the set of selected links, all occurrences of the attribute value in the target document **MUST** be updated using the value from the PATCH payload. If the attribute name is not present in any selected links, the attribute **MUST** be added to the links.

The update request interface is specified as follows:

Interaction: EP -> RD

Method: PATCH

URI Template: /{+location}{?href,rel,rt,if,ct}

URI Template Variables:

location := This is the Location path returned by the RD as a result of a successful earlier registration.

href,rel,rt,if,ct := link relations and attributes specified in the query in order to select particular links based on their relations and attributes. "href" denotes the URI target of the link. See [[RFC6690](#)] Sec. 4.1

Content-Format: application/merge-patch+json (mandatory)

The following response codes are defined for this interface:

Success: 2.04 "Changed" Or 204 "No Content" in the update was successfully processed.

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 4.04 "Not Found" or 404 "Not Found". Registration resource does not exist (e.g. may have expired).

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following examples show an endpoint adding </sensors/humid>, modifying </sensors/temp>, and removing </sensors/light> links in RD using the Update Endpoint Links function with the example location value /rd/4521.

The following example shows an EP adding the link </sensors/humid>;ct=41;rt="humid-s";if="sensor" to the collection of links at the location /rd/4521.

Req: PATCH /rd/4521

Payload:

```
[{"href":"/sensors/humid","ct": 41, "rt": "humid-s", "if": "sensor"}]
```

Content-Format:

application/merge-patch+json

Res: 2.04 Changed

The following example shows an EP modifying all links at the example location /rd/4521 which are identified by href="/sensors/temp", from the initial link-value of </sensors/temp>;rt="temperature" to the new

link-value </sensors/temp>;rt="temperature-c";if="sensor" by changing the value of the link attribute "rt" and adding the link attribute if="sensor" using the PATCH operation with the supplied merge-patch+json document payload.

Req: PATCH /rd/4521?href="/sensors/temp"

Payload:

```
{"rt": "temperature-c", "if": "sensor"},
```

Content-Format:

application/merge-patch+json

Res: 2.04 Changed

This example shows an EP removing all links at the example location /rd/4521 which are identified by href="/sensors/light".

Req: PATCH /rd/4521?href="/sensors/light"

Payload:

```
{null}
```

Content-Format:

application/merge-patch+json

Res: 2.04 Changed

7. Group Function Set

This section defines a function set for the creation of groups of endpoints for the purpose of managing and looking up endpoints for group operations. The group function set is similar to the resource directory function set, in that a group may be created or removed. However unlike an endpoint entry, a group entry consists of a list of endpoints and does not have a lifetime associated with it. In order to make use of multicast requests with CoAP, a group MAY have a multicast address associated with it.

7.1. Register a Group

In order to create a group, a commissioning tool (CT) used to configure groups, makes a request to the RD indicating the name of the group to create (or update), optionally the domain the group belongs to, and optionally the multicast address of the group. The registration message includes the list of endpoints that belong to that group.

All the endpoints in the group MUST be registered with the RD before registering a group. If an endpoint is not yet registered to the RD before registering the group, the registration message returns an error. The RD sends a blank target URI for every endpoint link when registering the group.

Configuration of the endpoints themselves is out of scope of this specification. Such an interface for managing the group membership of an endpoint has been defined in [[RFC7390](#)].

The registration request interface is specified as follows:

Interaction: CT -> RD

Method: POST

URI Template: `/[+rd-group]{?gp,d,con}`

URI Template Variables:

`rd-group` := RD Group Function Set path (mandatory). This is the path of the RD Group Function Set. The value "rd-group" is recommended for this variable.

`gp` := Group Name (mandatory). The name of the group to be created or replaced, unique within that domain. The maximum length of this parameter is 63 bytes.

`d` := Domain (optional). The domain to which this group belongs. The maximum length of this parameter is 63 bytes. Optional. When this parameter is elided, the RD MAY associate the endpoint with a configured default domain. The domain value is needed to export the endpoint to DNS-SD (see [Section 10](#))

`con` := Context (optional). This parameter is used to set the IP multicast address at which this server is available in the form `scheme://multicast-address:port`. Optional. In the absence of this parameter no multicast address is configured. This parameter is compulsory when the directory is filled by a commissioning tool.

Content-Format: `application/link-format`

Content-Format: `application/link-format+json`

Content-Format: `application/link-format+cbor`

The following response codes are defined for this interface:

Success: 2.01 "Created" or 201 "Created". The Location header MUST be included with the new group entry. This Location MUST be a stable identifier generated by the RD as it is used for delete operations on this registration.

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 4.04 "Not Found" or 404 "Not Found". An Endpoint is not registered in the RD (e.g. may have expired).

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following example shows an EP registering a group with the name "lights" which has two endpoints to an RD using this interface. The base location value /rd-group is an example of an RD base location.

Req: POST coap://rd.example.com/rd-group?gp=lights

Content-Format: 40

Payload:

<>;ep="node1",

<>;ep="node2"

Res: 2.01 Created

Location: /rd-group/12

Req: POST /rd-group?gp=lights HTTP/1.1

Host: example.com

Content-Type: application/link-format

Payload:

<>;ep="node1",

<>;ep="node2"

Res: 201 Created

Location: /rd-group/12

7.2. Group Removal

A group can be removed simply by sending a removal message to the location returned when registering the group. Removing a group MUST NOT remove the endpoints of the group from the RD.

The removal request interface is specified as follows:

Interaction: CT -> RD

Method: DELETE

URI Template: /{+location}

URI Template Variables:

location := This is the Location path returned by the RD as a result of a successful group registration.

The following responses codes are defined for this interface:

Success: 2.02 "Deleted" or 204 "No Content" upon successful deletion

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 4.04 "Not Found" or 404 "Not Found". Group does not exist.

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The following examples shows successful removal of the group from the RD with the example location value /rd-group/12.

Req: DELETE /rd-group/12

Res: 2.02 Deleted

8. RD Lookup Function Set

In order for an RD to be used for discovering resources registered with it, a lookup interface can be provided using this function set. This lookup interface is defined as a default, and it is assumed that RDs may also support lookups to return resource descriptions in alternative formats (e.g. Atom or HTML Link) or using more advanced interfaces (e.g. supporting context or semantic based lookup).

This function set allows lookups for domains, groups, endpoints and resources using attributes defined in the RD Function Set and for use with the CoRE Link Format. The result of a lookup request is the list of links (if any) corresponding to the type of lookup. Thus, a domain lookup MUST return a list of domains, a group lookup MUST return a list of groups, an endpoint lookup MUST return a list of endpoints and a resource lookup MUST return a list of links to resources.

Each endpoint and resource lookup result returns respectively the scheme (IP address and port) followed by the path part of the URI of every endpoint and resource inside angle brackets ("`<>`") and followed by the other parameters.

The target of these links SHOULD be the actual location of the domain, endpoint or resource, but MAY be an intermediate proxy e.g. in the case of an HTTP lookup interface for CoAP endpoints.

The domain lookup returns every lookup domain with a base RD resource value (e.g. `/rd`) encapsulated within angle brackets.

In case that a group does not implement any multicast address, the group lookup returns every group lookup with a group base resource value encapsulated within angle brackets (e.g. `/rd/look-up`). Otherwise, the group lookup returns the multicast address of the group inside angle brackets.

Using the Accept Option, the requester can control whether this list is returned in CoRE Link Format (`application/link-format`, default) or its alternate content-formats (`application/link-format+json` or `application/link-format+cbor`).

The page and count parameters are used to obtain lookup results in specified increments using pagination, where count specifies how many links to return and page specifies which subset of links organized in sequential pages, each containing 'count' links, starting with link zero and page zero. Thus, specifying count of 10 and page of 0 will return the first 10 links in the result set (links 0-9). Count = 10 and page = 1 will return the next 'page' containing links 10-19, and so on.

Multiple query parameters MAY be included in a lookup, all included parameters MUST match for a resource to be returned. The character '*' MAY be included at the end of a parameter value as a wildcard operator.

The rd-lookup interface MAY use any set of query parameters to match the registered attributes and relations. In addition, this interface MAY be used with queries that specify domains, endpoints, and groups. For example, a domain lookup filtering on groups would return a list of domains that contain the specified groups. An endpoint lookup filtering on groups would return a list of endpoints that are in the specified groups.

The lookup interface is specified as follows:

Interaction: Client -> RD

Method: GET

URI Template: `/{"rd-lookup-base"}/{lookup-type}{?d,ep,gp,et,rt,page,count,resource-param}`

URI Template Variables:

`rd-lookup-base` := RD Lookup Function Set path (mandatory). This is the path of the RD Lookup Function Set. The recommended value for this variable is: "rd-lookup".

`lookup-type` := ("d", "ep", "res", "gp") (mandatory) This variable is used to select the kind of lookup to perform (domain, endpoint, resource, or group).

`ep` := Endpoint name (optional). Used for endpoint, group and resource lookups.

`d` := Domain (optional). Used for domain, group, endpoint and resource lookups.

`res` := resource (optional). Used for domain, group, endpoint and resource lookups.

`gp` := Group name (optional). Used for endpoint, group and resource lookups.

`page` := Page (optional). Parameter can not be used without the count parameter. Results are returned from result set in pages that contain 'count' links starting from index (page * count). Page numbering starts with zero.

`count` := Count (optional). Number of results is limited to this parameter value. If the page parameter is also present, the response MUST only include 'count' links starting with the (page * count) link in the result set from the query. If the count parameter is not present, then the response MUST return all matching links in the result set. Link numbering starts with zero.

`rt` := Resource type (optional). Used for group, endpoint and resource lookups.

`et` := Endpoint type (optional). Used for group, endpoint and resource lookups.

resource-param := Link attribute parameters (optional). Any link attribute as defined in [Section 4.1 of \[RFC6690\]](#), used for resource lookups.

Content-Format: application/link-format (optional)

Content-Format: application/link-format+json (optional)

Content-Format: application/link-format+cbor (optional)

The following responses codes are defined for this interface:

Success: 2.05 "Content" or 200 "OK" with an "application/link-format", "application/link-format+cbor", or "application/link-format+json" payload containing matching entries for the lookup.

Failure: 4.04 "Not Found" or 404 "Not Found" in case no matching entry is found for a unicast request.

Failure: No error response to a multicast request.

Failure: 4.00 "Bad Request" or 400 "Bad Request". Malformed request.

Failure: 5.03 "Service Unavailable" or 503 "Service Unavailable". Service could not perform the operation.

HTTP support: YES

The examples in this section assume a CoAP host with IP address FDFD::123 and a default CoAP port 61616. HTTP hosts are possible and do not change the nature of the examples.\

The following example shows a client performing a resource lookup with the example look-up location /rd-lookup/:

Req: GET /rd-lookup/res?rt=temperature

Res: 2.05 Content
<coap://[FDFD::123]:61616/temp>;rt="temperature"

The following example shows a client performing an endpoint type lookup:

Req: GET /rd-lookup/ep?et=power-node

Res: 2.05 Content

```
<coap://[FDFD::123]:61616>;ep="node5",  
<coap://[FDFD::123]:61616>;ep="node7"
```

The following example shows a client performing a domain lookup:

Req: GET /rd-lookup/d

Res: 2.05 Content

```
<>;d="domain1",  
<>;d="domain2"
```

The following example shows a client performing a group lookup for all groups:

Req: GET /rd-lookup/gp

Res: 2.05 Content

```
<>;gp="lights1";d="example.com"  
<>;gp="lights2";d="example.com"
```

The following example shows a client performing a lookup for all endpoints in a particular group:

Req: GET /rd-lookup/ep?gp=lights1

Res: 2.05 Content

```
<coap://[FDFD::123]:61616>;ep="node1",  
<coap://[FDFD::123]:61616>;ep="node2"
```

The following example shows a client performing a lookup for all groups an endpoint belongs to:

Req: GET /rd-lookup/gp?ep=node1

Res: 2.05 Content

```
<>;gp="lights1"
```

The following example shows a client performing a paginated lookup

Req: GET /rd-lookup/res?page=0&count=5

Res: 2.05 Content

```
<coap://[FDFD::123]:61616/res/0>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/1>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/2>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/3>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/4>;rt=sensor;ct=60
```

Req: GET /rd-lookup/res?page=1&count=5

Res: 2.05 Content

```
<coap://[FDFD::123]:61616/res/5>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/6>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/7>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/8>;rt=sensor;ct=60
<coap://[FDFD::123]:61616/res/9>;rt=sensor;ct=60
```

9. New Link-Format Attributes

When using the CoRE Link Format to describe resources being discovered by or posted to a resource directory service, additional information about those resources is useful. This specification defines the following new attributes for use in the CoRE Link Format [\[RFC6690\]](#):

```
link-extension    = ( "ins" "=" (ptoken | quoted-string) )
                   ; The token or string is max 63 bytes
link-extension    = ( "exp" )
```

9.1. Resource Instance attribute 'ins'

The Resource Instance "ins" attribute is an identifier for this resource, which makes it possible to distinguish it from other similar resources. This attribute is similar in use to the <Instance> portion of a DNS-SD record (see [Section 10.1](#), and SHOULD be unique across resources with the same Resource Type attribute in the domain it is used. A Resource Instance might be a descriptive string like "Ceiling Light, Room 3", a short ID like "AF39" or a unique UUID or iNumber. This attribute is used by a Resource Directory to distinguish between multiple instances of the same resource type within the directory.

This attribute MUST be no more than 63 bytes in length. The resource identifier attribute MUST NOT appear more than once in a link description. This attribute MAY be used as a query parameter in the RD Lookup Function Set defined in [Section 7](#).

9.2. Export attribute 'exp'

The Export "exp" attribute is used as a flag to indicate that a link description MAY be exported by a resource directory to external directories.

The CoRE Link Format is used for many purposes between CoAP endpoints. Some are useful mainly locally, for example checking the observability of a resource before accessing it, determining the size of a resource, or traversing dynamic resource structures. However, other links are very useful to be exported to other directories, for example the entry point resource to a functional service. This attribute MAY be used as a query parameter in the RD Lookup Function Set defined in [Section 7](#).

10. DNS-SD Mapping

CoRE Resource Discovery is intended to support fine-grained discovery of hosted resources, their attributes, and possibly other resource relations [[RFC6690](#)]. In contrast, service discovery generally refers to a coarse-grained resolution of an endpoint's IP address, port number, and protocol.

Resource and service discovery are complementary in the case of large networks, where the latter can facilitate scaling. This document defines a mapping between CoRE Link Format attributes and DNS-Based Service Discovery [[RFC6763](#)] fields that permits discovery of CoAP services by either method.

10.1. DNS-based Service discovery

DNS-Based Service Discovery (DNS-SD) defines a conventional method of configuring DNS PTR, SRV, and TXT resource records to facilitate discovery of services (such as CoAP servers in a subdomain) using the existing DNS infrastructure. This section gives a brief overview of DNS-SD; see [[RFC6763](#)] for a detailed specification.

DNS-SD service names are limited to 255 octets and are of the form:

Service Name = <Instance>.<ServiceType>.<Domain>.

The service name is the label of SRV/TXT resource records. The SRV RR specifies the host and the port of the endpoint. The TXT RR provides additional information in the form of key/value pairs.

The <Domain> part of the service name is identical to the global (DNS subdomain) part of the authority in URIs that identify servers or groups of servers.

The <ServiceType> part is composed of at least two labels. The first label of the pair is the application protocol name [[RFC6335](#)] preceded by an underscore character. The second label indicates the transport and is always "_udp" for UDP-based CoAP services. In cases where narrowing the scope of the search may be useful, these labels may be optionally preceded by a subtype name followed by the "_sub" label. An example of this more specific <ServiceType> is "light._sub._dali._udp".

A default <Instance> part of the service name may be set at the factory or during the commissioning process. It SHOULD uniquely identify an instance of <ServiceType> within a <Domain>. Taken together, these three elements comprise a unique name for an SRV/ TXT record pair within the DNS subdomain.

The granularity of a service name MAY be that of a host or group, or it could represent a particular resource within a CoAP server. The SRV record contains the host name (AAAA record name) and port of the service while protocol is part of the service name. In the case where a service name identifies a particular resource, the path part of the URI must be carried in a corresponding TXT record.

A DNS TXT record is in practice limited to a few hundred octets in length, which is indicated in the resource record header in the DNS response message. The data consists of one or more strings comprising a key=value pair. By convention, the first pair is txtver=<number> (to support different versions of a service description).

10.2. mapping ins to <Instance>

The Resource Instance "ins" attribute maps to the <Instance> part of a DNS-SD service name. It is stored directly in the DNS as a single DNS label of canonical precomposed UTF-8 [[RFC3629](#)] "Net-Unicode" (Unicode Normalization Form C) [[RFC5198](#)] text. However, to the extent that the "ins" attribute may be chosen to match the DNS host name of a service, it SHOULD use the syntax defined in [Section 3.5 of \[RFC1034\]](#) and [Section 2.1 of \[RFC1123\]](#).

The <Instance> part of the name of a service being offered on the network SHOULD be configurable by the user setting up the service, so that he or she may give it an informative name. However, the device or service SHOULD NOT require the user to configure a name before it can be used. A sensible choice of default name can allow the device or service to be accessed in many cases without any manual configuration at all. The default name should be short and descriptive, and MAY include a collision-resistant substring such as the lower bits of the device's MAC address, serial number,

fingerprint, or other identifier in an attempt to make the name relatively unique.

DNS labels are currently limited to 63 octets in length and the entire service name may not exceed 255 octets.

10.3. Mapping rt to <ServiceType>

The resource type "rt" attribute is mapped into the <ServiceType> part of a DNS-SD service name and SHOULD conform to the reg-rel-type production of the Link Format defined in [Section 2 of \[RFC6690\]](#). The "rt" attribute MUST be composed of at least a single Net-Unicode text string, without underscore '_' or period '.' and limited to 15 octets in length, which represents the application protocol name. This string is mapped to the DNS-SD <ServiceType> by prepending an underscore and appending a period followed by the "_udp" label. For example, rt="dali" is mapped into "_dali._udp".

The application protocol name may be optionally followed by a period and a service subtype name consisting of a Net-Unicode text string, without underscore or period and limited to 63 octets. This string is mapped to the DNS-SD <ServiceType> by appending a period followed by the "_sub" label and then appending a period followed by the service type label pair derived as in the previous paragraph. For example, rt="dali.light" is mapped into "light._sub._dali._udp".

The resulting string is used to form labels for DNS-SD records which are stored directly in the DNS.

10.4. Domain mapping

DNS domains may be derived from the "d" attribute. The domain attribute may be suffixed with the zone name of the authoritative DNS server to generate the domain name. The "ep" attribute is prefixed to the domain name to generate the FQDN to be stored into DNS with an AAAA RR.

10.5. TXT Record key=value strings

A number of [\[RFC6763\]](#) key/value pairs are derived from link-format information, to be exported in the DNS-SD as key=value strings in a TXT record ([\[RFC6763\]](#), [Section 6.3](#)).

The resource <URI> is exported as key/value pair "path=<URI>".

The Interface Description "if" attribute is exported as key/value pair "if=<Interface Description>".

The DNS TXT record can be further populated by importing any other resource description attributes as they share the same key=value format specified in [Section 6 of \[RFC6763\]](#).

10.6. Importing resource links into DNS-SD

Assuming the ability to query a Resource Directory or multicast a GET (?exp) over the local link, CoAP resource discovery may be used to populate the DNS-SD database in an automated fashion. CoAP resource descriptions (links) can be exported to DNS-SD for exposure to service discovery by using the Resource Instance attribute as the basis for a unique service name, composed with the Resource Type as the <ServiceType>, and registered in the correct <Domain>. The agent responsible for exporting records to the DNS zone file SHOULD be authenticated to the DNS server. The following example, using the example lookup location /rd-lookup, shows an agent discovering a resource to be exported:

```
Req: GET /rd-lookup/res?exp
```

```
Res: 2.05 Content
```

```
<coap://[FDFD::1234]:5683/light/1>;  
exp;rt="dali.light";ins="Spot";  
d="office";ep="node1"
```

The agent subsequently registers the following DNS-SD RRs, assuming a zone name "example.com" prefixed with "office":

```
node1.office.example.com.      IN AAAA      FDFD::1234  
_dali._udp.office.example.com  IN PTR  
                               Spot._dali._udp.office.example.com  
light._sub._dali._udp.example.com  IN PTR  
                               Spot._dali._udp.office.example.com  
Spot._dali._udp.office.example.com IN SRV  0 0 5683  
                               node1.office.example.com.  
Spot._dali._udp.office.example.com IN TXT  
                               txtver=1;path=/light/1
```

In the above figure the Service Name is chosen as Spot._dali._udp.office.example.com without the light._sub service prefix. An alternative Service Name would be: Spot.light._sub._dali._udp.office.example.com.

11. Security Considerations

The security considerations as described in [Section 7 of \[RFC5988\]](#) and [Section 6 of \[RFC6690\]](#) apply. The `"/.well-known/core"` resource may be protected e.g. using DTLS when hosted on a CoAP server as described in [\[RFC7252\]](#). DTLS or TLS based security SHOULD be used on all resource directory interfaces defined in this document.

11.1. Endpoint Identification and Authentication

An Endpoint is determined to be unique by an RD by the Endpoint identifier parameter included during Registration, and any associated TLS or DTLS security bindings. An Endpoint MUST NOT be identified by its protocol, port or IP address as these may change over the lifetime of an Endpoint.

Every operation performed by an Endpoint or Client on a resource directory SHOULD be mutually authenticated using Pre-Shared Key, Raw Public Key or Certificate based security. Endpoints using a Certificate MUST include the Endpoint identifier as the Subject of the Certificate, and this identifier MUST be checked by a resource directory to match the Endpoint identifier included in the Registration message.

11.2. Access Control

Access control SHOULD be performed separately for the RD Function Set and the RD Lookup Function Set, as different endpoints may be authorized to register with an RD from those authorized to lookup endpoints from the RD. Such access control SHOULD be performed in as fine-grained a level as possible. For example access control for lookups could be performed either at the domain, endpoint or resource level.

11.3. Denial of Service Attacks

Services that run over UDP unprotected are vulnerable to unknowingly become part of a DDoS attack as UDP does not require return routability check. Therefore, an attacker can easily spoof the source IP of the target entity and send requests to such a service which would then respond to the target entity. This can be used for large-scale DDoS attacks on the target. Especially, if the service returns a response that is order of magnitudes larger than the request, the situation becomes even worse as now the attack can be amplified. DNS servers have been widely used for DDoS amplification attacks. There is also a danger that NTP Servers could become implicated in denial-of-service (DoS) attacks since they run on unprotected UDP, there is no return routability check, and they can

have a large amplification factor. The responses from the NTP server were found to be 19 times larger than the request. A Resource Directory (RD) which responds to wild-card lookups is potentially vulnerable if run with CoAP over UDP. Since there is no return routability check and the responses can be significantly larger than requests, RDs can unknowingly become part of a DDoS amplification attack. Therefore, it is RECOMMENDED that implementations ensure return routability. This can be done, for example by responding to wild card lookups only over DTLS or TLS or TCP.

12. IANA Considerations

12.1. Resource Types

"core.rd", "core.rd-group" and "core.rd-lookup" resource types need to be registered with the resource type registry defined by [\[RFC6690\]](#).

12.2. Link Extension

The "exp" and "ins" attributes need to be registered when a future Web Linking link-extension registry is created (e.g. in RFC5988bis).

12.3. IPv6 ND Resource Directory Address Option

This document registers one new ND option type under the subregistry "IPv6 Neighbor Discovery Option Formats":

- o Resource Directory address Option (38)

12.4. RD Parameter Registry

This specification defines a new sub-registry for registration and lookup parameters called "RD Parameters" under "CoRE Parameters". Although this specification defines a basic set of parameters, it is expected that other standards that make use of this interface will define new ones.

Each entry in the registry must include the human readable name of the parameter, the query parameter, validity requirements if any and a description. The query parameter MUST be a valid URI query key [\[RFC3986\]](#).

Initial entries in this sub-registry are as follows:

Name	Query	Validity	Description
Endpoint Name	ep		Name of the endpoint, max 63 bytes
Lifetime	lt	60-4294967295	Lifetime of the registration in seconds
Domain	d		Domain to which this endpoint belongs
Endpoint Type	et		Semantic name of the endpoint
Context	con	URI	The scheme, address and port at which this server is available
Resource Name	res		Name of the resource
Group Name	gp		Name of a group in the RD
Page Count	page	Integer	Used for pagination
Resource Instance	count	Integer	Used for pagination
Export	ins		Instance Identifier
	exp		A link MAY be exported to another Resource Directory

Table 1: RD Parameters

The IANA policy for future additions to the sub-registry is "Expert Review" as described in [[RFC5226](#)].

13. Examples

13.1. Lighting Installation

This example shows a simplified lighting installation which makes use of the Resource Directory (RD) with a CoAP interface to facilitate the installation and start up of the application code in the lights and sensors. In particular, the example leads to the definition of a group and the enabling of the corresponding multicast address. No conclusions must be drawn on the realization of actual installation or naming procedures, because the example only "emphasizes" some of the issues that may influence the use of the RD and does not pretend to be normative. The example uses the recommended values for the base resources: "/rd", "/rd-lookup", and "/rd-group".

13.1.1. Installation Characteristics

The example assumes that the installation is managed. That means that a Commissioning Tool (CT) is used to authorize the addition of nodes, name them, and name their services. The CT can be connected to the installation in many ways: the CT can be part of the installation network, connected by WiFi to the installation network, or connected via GPRS link, or other method.

It is assumed that there are two naming authorities for the installation: (1) the network manager that is responsible for the correct operation of the network and the connected interfaces, and (2) the lighting manager that is responsible for the correct functioning of networked lights and sensors. The result is the existence of two naming schemes coming from the two managing entities.

The example installation consists of one presence sensor, and two luminaries, luminary1 and luminary2, each with their own wireless interface. Each luminary contains three lamps: left, right and middle. Each luminary is accessible through one endpoint. For each lamp a resource exists to modify the settings of a lamp in a luminary. The purpose of the installation is that the presence sensor notifies the presence of persons to a group of lamps. The group of lamps consists of: middle and left lamps of luminary1 and right lamp of luminary2.

Before commissioning by the lighting manager, the network is installed and access to the interfaces is proven to work by the network manager.

At the moment of installation, the network under installation is not necessarily connected to the DNS infra structure. Therefore, SLAAC IPv6 addresses are assigned to CT, RD, luminaries and sensor shown in Table 2 below:

+-----+-----+	
Name	IPv6 address
+-----+-----+	
luminary1	FDFD::ABCD:1
luminary2	FDFD::ABCD:2
Presence sensor	FDFD::ABCD:3
Resource directory	FDFD::ABCD:0
+-----+-----+	

Table 2: interface SLAAC addresses

In [Section 13.1.2](#) the use of resource directory during installation is presented. In [Section 13.1.3](#) the connection to DNS is discussed.

13.1.2. RD entries

It is assumed that access to the DNS infrastructure is not always possible during installation. Therefore, the SLAAC addresses are used in this section.

For discovery, the resource types (rt) of the devices are important. The lamps in the luminaries have rt: light, and the presence sensor has rt: p-sensor. The endpoints have names which are relevant to the light installation manager. In this case luminary1, luminary2, and the presence sensor are located in room 2-4-015, where luminary1 is located at the window and luminary2 and the presence sensor are located at the door. The endpoint names reflect this physical location. The middle, left and right lamps are accessed via path /light/middle, /light/left, and /light/right respectively. The identifiers relevant to the Resource Directory are shown in Table 3 below:

Name	endpoint	resource path	resource type
luminary1	lm_R2-4-015_wndw	/light/left	light
luminary1	lm_R2-4-015_wndw	/light/middle	light
luminary1	lm_R2-4-015_wndw	/light/right	light
luminary2	lm_R2-4-015_door	/light/left	light
luminary2	lm_R2-4-015_door	/light/middle	light
luminary2	lm_R2-4-015_door	/light/right	light
Presence sensor	ps_R2-4-015_door	/ps	p-sensor

Table 3: Resource Directory identifiers

The CT inserts the endpoints of the luminaries and the sensor in the RD using the Context parameter (con) to specify the interface address:


```
Req: POST coap://[FDFD::ABCD:0]/rd
    ?ep=lm_R2-4-015_wndw&con=coap://[FDFD::ABCD:1]
Payload:
</light/left>;rt="light"; d="R2-4-015",
</light/middle>;rt="light"; d="R2-4-015",
</light/right>;rt="light";d="R2-4-015"

Res: 2.01 Created
Location: /rd/4521
```

```
Req: POST coap://[FDFD::ABCD:0]/rd
    ?ep=lm_R2-4-015_door&con=coap://[FDFD::ABCD:2]
Payload:
</light/left>;rt="light"; d="R2-4-015",
</light/middle>;rt="light"; d="R2-4-015",
</light/right>;rt="light"; d="R2-4-015"

Res: 2.01 Created
Location: /rd/4522
```

```
Req: POST coap://[FDFD::ABCD:0]/rd
    ?ep=ps_R2-4-015_door&con=coap://[FDFD::ABCD:3]
Payload:
</ps>;rt="p-sensor"; d="R2-4-015"

Res: 2.01 Created
Location: /rd/4523
```

The domain name d="R2-4-015" has been added for an efficient lookup because filtering on "ep" name is more awkward. The same domain name is communicated to the two luminaries and the presence sensor by the CT.

The group is specified in the RD. The Context parameter is set to the site-local multicast address allocated to the group. In the POST in the example below, these two endpoints and the endpoint of the presence sensor are registered as members of the group.

```
Req: POST coap://[FDFD::ABCD:0]/rd-group
    ?gp=grp_R2-4-015;con="coap://[FF05::1]";exp;ins="grp1234"
Payload:
<>ep=lm_R2-4-015_wndw,
<>ep=lm_R2-4-015_door,
<>ep=ps_R2-4-015_door

Res: 2.01 Created
Location: /rd-group/501
```


After the filling of the RD by the CT, the application in the luminaries can learn to which groups they belong, and enable their interface for the multicast address.

The luminary, knowing its domain, queries the RD for the endpoint with `rt=light` and `d=R2-4-015`. The RD returns all endpoints in the domain.

```
Req: GET coap://[FDFD::ABCD:0]/rd-lookup/ep
     ?d=R2-4-015;rt=light
```

```
Res: 2.05 Content
<coap://[FDFD::ABCD:1]>;
  ep="lm_R2-4-015_wndw",
<coap://[FDFD::ABCD:2]>;
  ep="lm_R2-4-015_door"
```

Knowing its own IPv6 address, the luminary discovers its endpoint name. With the endpoint name the luminary queries the RD for all groups to which the endpoint belongs.

```
Req: GET coap://[FDFD::ABCD:0]/rd-lookup/gp
     ?ep=lm_R2-4-015_wndw
```

```
Res: 2.05 Content
<coap://[FF05::1]>;gp="grp_R2-4-015"
```

From the context parameter value, the luminary learns the multicast address of the multicast group.

Alternatively, the CT can communicate the multicast address directly to the luminaries by using the "coap-group" resource specified in [\[RFC7390\]](#).

```
Req: POST //[FDFD::ABCD:1]/coap-group
     Content-Format: application/coap-group+json
     { "a": "[FF05::1]",
       "n": "grp_R2-4-015"}
```

```
Res: 2.01 Created
Location-Path: /coap-group/1
```

Dependent on the situation, only the address, "a", or the name, "n", is specified in the coap-group resource.

13.1.3. DNS entries

It may be profitable to discover the light groups for applications, which are unaware of the existence of the RD. An agent needs to query the RD to return all groups which are exported to be inserted into DNS.

Req: GET /rd-lookup/gp?exp

Res: 2.05 Content

```
<coap://[FF05::1]/>;exp;gp="grp_R2-4-015;ins="grp1234";  
ep="lm_R2-4-015_wndw";  
ep="lm_R2-4-015_door"
```

The group with FQDN `grp_R2-4-015.bc.example.com` can be entered into the DNS by the agent. The accompanying instance name is `grp1234`. The `<ServiceType>` is chosen to be `_group._udp`. The agent enters the following RRs into the DNS.

```
grp_R2-4-015.bc.example.com.      IN AAAA      FF05::1  
_group._udp.bc.example.com      IN PTR  
                                grp1234._group._udp.bc.example.com  
grp1234._group._udp.bc.example.com IN SRV  0 0 5683  
                                grp_R2-4-015_door.bc.example.com.  
grp1234._group._udp.bc.example.com IN TXT  
                                txtver=1;path=/light/grp1
```

From then on applications, not familiar with the existence of the RD, can use DNS to access the lighting group.

13.2. OMA Lightweight M2M (LWM2M) Example

This example shows how the OMA LWM2M specification makes use of Resource Directory (RD).

OMA LWM2M is a profile for device services based on CoAP(OMA Name Authority). LWM2M defines a simple object model and a number of abstract interfaces and operations for device management and device service enablement.

An LWM2M server is an instance of an LWM2M middleware service layer, containing a Resource Directory along with other LWM2M interfaces defined by the LWM2M specification.

CoRE Resource Directory (RD) is used to provide the LWM2M Registration interface.

LWM2M does not provide for registration domains and does not currently use the rd-group or rd-lookup interfaces.

The LWM2M specification describes a set of interfaces and a resource model used between a LWM2M device and an LWM2M server. Other interfaces, proxies, applications, and function sets are currently out of scope for LWM2M.

The location of the LWM2M Server and RD Function Set is provided by the LWM2M Bootstrap process, so no dynamic discovery of the RD function set is used. LWM2M Servers and endpoints are not required to implement the ./well-known/core resource.

13.2.1. The LWM2M Object Model

The OMA LWM2M object model is based on a simple 2 level class hierarchy consisting of Objects and Resources.

An LWM2M Resource is a REST endpoint, allowed to be a single value or an array of values of the same data type.

An LWM2M Object is a resource template and container type that encapsulates a set of related resources. An LWM2M Object represents a specific type of information source; for example, there is a LWM2M Device Management object that represents a network connection, containing resources that represent individual properties like radio signal strength.

Since there may potentially be more than one of a given type object, for example more than one network connection, LWM2M defines instances of objects that contain the resources that represent a specific physical thing.

The URI template for LWM2M consists of a base URI followed by Object, Instance, and Resource IDs:

```
{/base-uri}/{/object-id}/{/object-instance}/{/resource-id}/{/resource-instance}
```

The five variables given here are strings. base-uri can also have the special value "undefined" (sometimes called "null" in [RFC 6570](#)). Each of the variables object-instance, resource-id, and resource-instance can be the special value "undefined" only if the values behind it in this sequence also are "undefined". As a special case, object-instance can be "empty" (which is different from "undefined") if resource-id is not "undefined". [[TEMPLATE TODO](#)]

base-uri := Base URI for LWM2M resources or "undefined" for default (empty) base URI

object-id := OMNA (OMA Name Authority) registered object ID (0-65535)

object-instance := Object instance identifier (0-65535) or "undefined"/"empty" (see above)) to refer to all instances of an object ID

resource-id := OMNA (OMA Name Authority) registered resource ID (0-65535) or "undefined" to refer to all resources within an instance

resource-instance := Resource instance identifier or "undefined" to refer to single instance of a resource

LWM2M IDs are 16 bit unsigned integers represented in decimal (no leading zeroes except for the value 0) by URI format strings. For example, a LWM2M URI might be:

/1/0/1

The base uri is empty, the Object ID is 1, the instance ID is 0, the resource ID is 1, and the resource instance is "undefined". This example URI points to internal resource 1, which represents the registration lifetime configured, in instance 0 of a type 1 object (LWM2M Server Object).

13.2.2. LWM2M Register Endpoint

LWM2M defines a registration interface based on the Resource Directory Function Set, described in [Section 6](#). The URI of the LWM2M Resource Directory function set is specified to be "/rd" as recommended in [Section 6.3](#).

LWM2M endpoints register object IDs, for example </1>, to indicate that a particular object type is supported, and register object instances, for example </1/0>, to indicate that a particular instance of that object type exists.

Resources within the LWM2M object instance are not registered with the RD, but may be discovered by reading the resource links from the object instance using GET with a CoAP Content-Format of application/link-format. Resources may also be read as a structured object by performing a GET to the object instance with a Content-Format of senml+json.

When an LWM2M object or instance is registered, this indicates to the LWM2M server that the object and its resources are available for management and service enablement (REST API) operations.

LWM2M endpoints may use the following RD registration parameters as defined in Table 1 :

ep - Endpoint Name

lt - registration lifetime

Endpoint Name is mandatory, all other registration parameters are optional.

Additional optional LWM2M registration parameters are defined:

Name	Query	Validity	Description
Protocol Binding	b	{"U", "UQ", "S", "SQ", "US", "UQS"}	Available Protocols
LWM2M Version	ver	1.0	Spec Version
SMS Number	sms		MSISDN

Table 4: LWM2M Additional Registration Parameters

The following RD registration parameters are not currently specified for use in LWM2M:

et - Endpoint Type

con - Context

The endpoint registration must include a payload containing links to all supported objects and existing object instances, optionally including the appropriate link-format relations.

Here is an example LWM2M registration payload:

```
</1>,</1/0>,</3/0>,</5>
```

This link format payload indicates that object ID 1 (LWM2M Server Object) is supported, with a single instance 0 existing, object ID 3 (LWM2M Device object) is supported, with a single instance 0 existing, and object 5 (LWM2M Firmware Object) is supported, with no existing instances.

13.2.3. Alternate Base URI

If the LWM2M endpoint exposes objects at a base URI other than the default empty base path, the endpoint must register the base URI using `rt="oma.lwm2m"`. An example link payload using alternate base URI would be:

```
</my_lwm2m>;rt="oma.lwm2m",</my_lwm2m/1>,<my_lwm2m/1/0>,<my_lwm2m/5>
```

This link payload indicates that the lwm2m objects will be placed under the base URI `"/my_lwm2m"` and that object ID 1 (server) is supported, with a single instance 0 existing, and object 5 (firmware update) is supported.

13.2.4. LWM2M Update Endpoint Registration

An LWM2M Registration update proceeds as described in [Section 6.4](#), and adds some optional parameter updates:

lt - Registration Lifetime
b - Protocol Binding
sms - MSISDN
link payload - new or modified links

A Registration update is also specified to be used to update the LWM2M server whenever the endpoint's UDP port or IP address are changed.

13.2.5. LWM2M De-Register Endpoint

LWM2M allows for de-registration using the delete method on the returned location from the initial registration operation. LWM2M de-registration proceeds as described in [Section 6.5](#).

14. Acknowledgments

Oscar Novo, Srdjan Krco, Szymon Sasin, Kerry Lynn, Esko Dijk, Anders Brandt, Matthieu Vial, Mohit Sethi, Sampo Ukkola and Linyi Tian have provided helpful comments, discussions and ideas to improve and shape this document. [Section 9](#) is based on an earlier draft by Kerry Lynn. Zach would also like to thank his colleagues from the EU FP7 SENSEI project, where many of the resource directory concepts were originally developed.

15. Changelog

changes from -08 to -09

- o clarified the "example use" of the base RD resource values /rd, /rd-lookup, and /rd-group.
- o changed "ins" ABNF notation.
- o various editorial improvements, including in examples
- o clarifications for RDA0

changes from -07 to -08

- o removed link target value returned from domain and group lookup types
- o Maximum length of domain parameter 63 bytes for consistency with group
- o removed option for simple POST of link data, don't require a .well-known/core resource to accept POST data and handle it in a special way; we already have /rd for that
- o add IPV6 ND Option for discovery of an RD
- o clarify group configuration [section 6.1](#) that endpoints must be registered before including them in a group
- o removed all superfluous client-server diagrams
- o simplified lighting example
- o introduced Commissioning Tool
- o RD-Look-up text is extended.

changes from -06 to -07

- o added text in the discovery section to allow content format hints to be exposed in the discovery link attributes
- o editorial updates to [section 9](#)
- o update author information
- o minor text corrections

Changes from -05 to -06

- o added note that the PATCH section is contingent on the progress of the PATCH method

changes from -04 to -05

- o added Update Endpoint Links using PATCH
- o http access made explicit in interface specification
- o Added http examples

Changes from -03 to -04:

- o Added http response codes
- o Clarified endpoint name usage
- o Add application/link-format+cbor content-format

Changes from -02 to -03:

- o Added an example for lighting and DNS integration
- o Added an example for RD use in OMA LWM2M
- o Added Read Links operation for link inspection by endpoints
- o Expanded DNS-SD section
- o Added draft authors Peter van der Stok and Michael Koster

Changes from -01 to -02:

- o Added a catalogue use case.
- o Changed the registration update to a POST with optional link format payload. Removed the endpoint type update from the update.
- o Additional examples section added for more complex use cases.
- o New DNS-SD mapping section.
- o Added text on endpoint identification and authentication.
- o Error code 4.04 added to Registration Update and Delete requests.

- o Made 63 bytes a SHOULD rather than a MUST for endpoint name and resource type parameters.

Changes from -00 to -01:

- o Removed the ETag validation feature.
- o Place holder for the DNS-SD mapping section.
- o Explicitly disabled GET or POST on returned Location.
- o New registry for RD parameters.
- o Added support for the JSON Link Format.
- o Added reference to the Groupcomm WG draft.

Changes from -05 to WG Document -00:

- o Updated the version and date.

Changes from -04 to -05:

- o Restricted Update to parameter updates.
- o Added pagination support for the Lookup interface.
- o Minor editing, bug fixes and reference updates.
- o Added group support.
- o Changed rt to et for the registration and update interface.

Changes from -03 to -04:

- o Added the ins= parameter back for the DNS-SD mapping.
- o Integrated the Simple Directory Discovery from Carsten.
- o Editorial improvements.
- o Fixed the use of ETags.
- o Fixed tickets 383 and 372

Changes from -02 to -03:

- o Changed the endpoint name back to a single registration parameter ep= and removed the h= and ins= parameters.
- o Updated REST interface descriptions to use [RFC6570](#) URI Template format.
- o Introduced an improved RD Lookup design as its own function set.
- o Improved the security considerations section.
- o Made the POST registration interface idempotent by requiring the ep= parameter to be present.

Changes from -01 to -02:

- o Added a terminology section.
- o Changed the inclusion of an ETag in registration or update to a MAY.
- o Added the concept of an RD Domain and a registration parameter for it.
- o Recommended the Location returned from a registration to be stable, allowing for endpoint and Domain information to be changed during updates.
- o Changed the lookup interface to accept endpoint and Domain as query string parameters to control the scope of a lookup.

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Editorial Comments

[_TEMPLATE_TODO] This text needs some help from an [RFC 6570](#) expert.

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