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C. Bormann
Universitaet Bremen TZI

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CoRE Roadmap and Implementation Guide
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Abstract

The CoRE set of protocols, in particular the CoAP protocol, is defined in draft-ietf-core-coap in conjunction with a number of specifications that are currently nearing completion. There are also several dozen more individual Internet-Drafts in various states of development, with various levels of WG review and interest.

Today, this is simply a bewildering array of documents. Beyond the main four documents, it is hard to find relevant information and assess the status of proposals. At the level of Internet-Drafts, the IETF has only adoption as a WG document to assign status - too crude an instrument to assess the level of development and standing for anyone who does not follow the daily proceedings of the WG.

With a more long-term perspective, as additional drafts mature and existing specifications enter various levels of spec maintenance, the entirety of these specifications may become harder to understand, pose specific implementation problems, or be simply inconsistent.

The present guide aims to provide a roadmap to these documents as well as provide specific advice how to use these specifications in combination. In certain cases, it may provide clarifications or even corrections to the specifications referenced.

This guide is intended as a continued work-in-progress, i.e. a long-lived Internet-Draft, to be updated whenever new information becomes available and new consensus on how to handle issues is formed. Similar to the ROHC implementation guide, RFC 4815, it might be published as an RFC at some future time later in the acceptance curve of the specifications.

This document does not describe a new protocol or attempt to set a new standard of any kind - it mostly describes good practice in using the existing specifications, but it may also document emerging consensus where a correction needs to be made.

(TODO: The present version does not completely cover the new Internet-Drafts submitted concurrently with it; it is to be updated by the start of IETF88.)

Status of This Memo

Copyright Notice

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1. Introduction

(To be written - for now please see the Abstract.)

1.1. Terminology

This document is a guide. However, it might evolve to make specific recommendations on how to use standards-track specifications. Therefore: 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. They indicate requirement levels for compliant CoRE implementations [RFC2119]. Note that these keywords are not only used where a correction or clarification is intended; the latter are explicitly identified as such.

The term "byte" is used in its now customary sense as a synonym for "octet".

2. The Main Four

The main component of the CoRE architecture is the Constrained Application Protocol (CoAP). It aims to provide a RESTful transfer service, not unlike HTTP, but radically simplified for the use on constrained devices on constrained networks. REST is the architectural style that informed the design of HTTP [REST]. The terms "constrained device" and "constrained network" refer to limited-capability devices such as sensors operating on networks such

as the IEEE 802.15.4 based 6LoWPAN [RFC4919].
[I-D.ietf-lwig-terminology] provides a more detailed discussion of what we mean by these terms.

2.1. The CoAP protocol

The CoAP protocol is defined in three specifications:

- [I-D.ietf-core-coap]
- [I-D.ietf-core-block]
- [I-D.ietf-core-observe]

The first specification, [I-D.ietf-core-coap], provides the core transfer protocol, including the means to provide communication security using the DTLS protocol [RFC6347] (compare this to the way [RFC2616] and [RFC2818] define HTTP and HTTPS). The protocol is structured into a message layer, which provides duplicate detection and optional message reliability on top of UDP, and a request/response layer, which provides the usual REST operations GET, PUT, POST, and DELETE. A highly efficient protocol encoding carries the 4-byte base header, a sequence of _Options_, and the payload (body) of a message. The main extension points of CoAP are its Options, similar to the way new header fields are used to extend HTTP.

Since CoAP is a very simple protocol running on top of UDP, it is limited in its transfer size by the datagram sizes provided by UDP. As a further constraint, many constrained networks do not provide good reliability of delivery once their small frame sizes are exceeded and the adaptation layer is forced to fragment [WEI]. This may lead to a practical limitation to payload sizes as small as 64 bytes. [I-D.ietf-core-block] extends the base CoAP protocol with three options that enable _blockwise_ transfer, i.e., splitting up a larger transfer into a sequence of smaller transactions, as well as the early determination of the overall size of the resource representation.

In HTTP, transactions are always client initiated, and it is the responsibility of the client to perform GET operations again and again (polling) if it wants to stay up to date about the status of a resource. This "pull model" becomes expensive in an environment with limited power, limited network resources, and nodes that sleep most of the time. Some more or less savory workarounds have been developed for HTTP [RFC6202], but, as a new protocol, CoAP can do better. [I-D.ietf-core-observe] extends the base CoAP protocol with an option that a client can use to indicate its interest in further updates from a resource. If the server accepts this option, the

client becomes an _Observer_ of this resource and receives an asynchronous notification message each time it changes. Each such notification message is identical in structure to the response to the initial GET request.

While the "Block" and "Observe" specifications are optional additions to the CoAP protocol (just as the core specification already defines 14 options most of which will not need to be used in every message), they together form what is now generally considered to be the CoAP protocol.

The CoRE Working Group has completed its work on the base CoAP protocol specification [I-D.ietf-core-coap] and it has been approved by the IESG for publication as a Standards-Track RFC on 2013-07-15. The completed document is currently waiting in the RFC editor queue for two of its normative references in the security area, [I-D.mcgrew-tls-aes-ccm-ecc] and [I-D.ietf-tls-oob-pubkey], to be completed and approved.

The other two CoAP specifications are, at the time of this writing, in the process of being updated based on the comments to the first Working-Group Last-Call [RFC2418], and in the second Working-Group Last-Call, respectively; these are prerequisites to submitting them to the IESG for publication as a Standards-Track RFC.

The specifications, together with link-format (below), have been widely implemented in highly interoperable implementations: an ETSI "plugtest" event in March 2012 was attended by 15 organizations with 20 implementations; in over 3000 tests performed only about 6 % failed; a second plugtest was conducted in November 2012 and led to some final adjustments of some details in the specifications. Another plugtest is planned for November 2013 [COAP3].

2.2. Discovery

The fourth specification in the main set now nearing completion does not extend the CoAP protocol but addresses a different problem.

In the Web, a number of methods for discovery of resources are common. Initially, Web discovery was just performed by humans based on an entry resource to a server (e.g., "/index.html"). This resource then includes links that directly or indirectly allow a human to reach the other Web resources that make up the Web site.

Web discovery can be performed by machines if standardized interfaces and resource descriptions are available. Among the component mechanisms for Web discovery that are standardized in the IETF are the well-known resource path "/.well-known/..." [RFC5785] and the

HTTP link header [RFC5988]. Several related techniques are in common use today.

Clearly, in the machine-to-machine environments that will be typical of CoAP applications, it is important to enable devices to discover each other and their resources. Autonomous devices and embedded systems necessitate uniform, interoperable resource discovery.

A basic component for this is provided by a standardized description format for the resources a server provides, the _link-format_. Unless other methods of discovery are available, CoAP servers should provide such a description via the well-known URI "/.well-known/core", available for access via a GET request on that URI. (More advanced resource discovery schemes might make the same description available by other means, e.g. by posting it to a resource directory.)

The description format has been adapted from the format used in the HTTP link header [RFC5988], which is simple and easy to parse. In contrast to the HTTP specification, link-format is specified as an Internet media type (what used to be called "MIME type") and intended to be carried around in the payload [RFC6690].

[RFC6690] was the first RFC of the CoRE working group.

2.3. Further reading

A recent article provides a more detailed overview over the CoRE documents nearing completion [SB].

While the specification documents themselves have to go into meticulous details on every aspect of their protocols, they are the ultimate reference source and are the recommended reading if this basic overview is not sufficient.

3. Informational Drafts

3.1. Implementation

In the IETF, a separate working group is working on informational documents concerning guidance in lightweight implementation of protocols, the LWIG working group. LWIG has several drafts pertinent here:

[I-D.ietf-lwig-terminology] provides some common terms that are useful for discussing implementations and specification in the constrained node network space. Section 2 and 3 of this document are quite stable at this time; a new section 4 is in preparation that

will include discussion of power-related terminology. [I-D.ietf-lwig-cellular] provides a well-founded discussion of methods for power conservation in CoAP nodes connected via cellular networks, from which some of the material will be used.

[I-D.ietf-lwig-guidance] was originally intended as the main working document of the WG. It contains some discussion about CoAP implementation in its section 3.4.2, including the efficient representation of managing duplicate detection state. [I-D.kovatsch-lwig-class1-coap] contains additional considerations that, over time, might move into [I-D.ietf-lwig-guidance]. [I-D.castellani-lwig-coap-separate-responses] contains some examples for message exchanges, focusing on elaborating exchanges involving separate responses. Since IETF86, work is under way to merge the CoAP-related information from these three drafts into a new document, [I-D.kovatsch-lwig-coap].

A new working group has been established in the IETF Security Area to address the use of DTLS In Constrained Environments (DICE); several drafts are available for discussion at IETF88 in Vancouver. On the implementation side, two drafts show how to build minimal implementations of security protocols relevant for CoAP: [I-D.ietf-lwig-tls-minimal] for TLS, which is relevant for CoAP's use of DTLS; and [I-D.ietf-lwig-ikev2-minimal] for IKEv2, the protocol for setting up IPsec security associations. Similarly, [I-D.hartke-core-codtls] looks specifically into the use of DTLS in constrained networks. It raises issues that pertain both to the LWIG and CoRE working groups of the IETF.

Further drafts submitted to LWIG address energy efficient implementation [I-D.hex-lwig-energy-efficient] and recent developments in operating systems for constrained devices [I-D.hahm-lwig-painless-constrained-programming].

After a somewhat slow start, LWIG is now picking up considerable energy.

3.2. Multicast and Group Communication

As it is based on UDP, CoAP easily supports the use of IP multicast to confer messages. However, there are difficult issues around making the desirable multicast applications actually work well.

This led to an additional milestone on the CoRE charter:

Nov 2012: Using CoAP for group communications to IESG as Informational

The informational WG draft [I-D.ietf-core-groupcomm] discusses fundamentals and use cases for group communication with CoAP. This is now very close to Working Group last call.

[I-D.dijk-core-groupcomm-misc] gives some additional considerations, listing requirements, providing some taxonomy, proposing deployment guidelines, and discussing approaches that are not (yet?) in the focus of the WG. Its section 5 can serve as an overview over the status of multicast in constrained node/networks.

3.3. Security

Several individual drafts analyze the issues around the security of constrained devices in constrained networks.

[I-D.garcia-core-security] in particular describes the "Thing Lifecycle" and discusses resulting architectural considerations.

[I-D.sarikaya-core-secure-bootsolution] documents the approach taken in the ZigBee IP specification (used in Smart Energy Profile 2.0); the CoRE WG currently is not working on replicating this specification as an IETF document.
[I-D.jennings-core-transitive-trust-enrollment] demonstrates a specific approach to securing the Thing Lifecycle based on defined roles of security players, including a Manufacturer, an Introducer, and a Transfer Agent. There is considerable interest in the CoRE working group to complete one or more specifications in this space.

Further work around Thing Lifecycles was expected to occur in the SOLACE initiative (Smart Object Lifecycle Architecture for Constrained Environments), with its early mailing list at solace@ietf.org -- developed after the model of the COMAN initiative (Management for Constrained Management Networks and Devices, coman@ietf.org, [I-D.ersue-constrained-mgmt]).

Besides [I-D.garcia-core-security], recently, more work has been focused on the Authentication and Authorization aspects of CoRE:

- [I-D.gerdes-core-dcaf-authorize]
- [I-D.greevenbosch-core-authreq]
- [I-D.pporamba-dtls-certkey]
- [I-D.urien-core-racs]
- [I-D.schmitt-two-way-authentication-for-iot]

- [I-D.seitz-core-sec-usecases]
- [I-D.selander-core-access-control]
- [I-D.zhu-core-groupauth]

3.4. Intermediaries

[I-D.castellani-core-http-mapping] discusses some ideas about what HTTP/CoAP intermediaries could do beyond the basic mapping defined in [I-D.ietf-core-coap]; in the IETF86 WG meeting, this document was agreed as a future working group item (with validation of the adoption on the mailing list still pending). An earlier version of this draft was split into the current document describing best practices for mapping between HTTP and CoAP (beyond what is already described in [I-D.ietf-core-coap]), and one additional document that describes usages that serve as additional useful examples for more advanced forms of mapping, a first draft of the latter is available in [I-D.castellani-core-advanced-http-mapping].

3.5. Congestion Control

[I-D.ietf-core-coap] only defines a very basic congestion control scheme that is focused on being safe in a wide variety of applications. Additional documents will define more advanced congestion control schemes that can provide more optimized performance in exchange for more implementation complexity and/or a narrower field of application.

Several drafts are contributing to this active subject of discussion in the WG:

draft-bormann-core-congestion-control	-02	2012-08-01
draft-bormann-core-cocoa	-00	2012-08-13

[I-D.greevenbosch-core-minimum-request-interval] proposes adding an option that allows a server to indicate its desire for some pacing of the requests sent to it by one client; enabling a form of server load control.

4. CoAP over X

[I-D.becker-core-coap-sms-gprs] shows how to run CoAP over cellular SMS and in mixed SMS/GPRS environments. This draft optionally makes use of an SMS-oriented encoding for CoAP that is described in [I-D.bormann-coap-misc].
[I-D.silverajan-core-coap-alternative-transports] discusses how to indicate the alternative transport in a URI.

[I-D.li-core-coap-payload-length-option] defines a way to indicate the length of the payload in case the underlying transport does not provide a suitable definite length indication.

5. Optional components of CoRE

Additional sub-protocols are being discussed in the IETF that may become optional protocols in CoREs.

The present document will track these sub-protocols and be amended once the sub-protocols reach formal status in the IETF.

Since the WG is cautious in adopting additional work while the main specifications near completion, none of the additional protocols proposed have become WG documents yet.

5.1. CoAP-misc

One draft is a little different from the other drafts in this category: [I-D.bormann-coap-misc] is a running document capturing CoAP extensions that are in various states of being cooked.

Some of these extensions may finally be adopted for the WG documents and then vanish from CoAP-misc. For other extensions, we may decide that they are not very good ideas. Instead of deleting them from CoAP-misc, they are moved to an appendix. This documents the approach, the best implementation of that approach that was reached, and the reasons why it was not adopted. This documentation should spare the WG and its contributors from the continuous reinvention of bad ideas.

As of the time of writing, the main body of CoAP-misc is almost empty, as most urgent developments have found their way into the WG documents, and many other ideas wait in the "nursery" section of the document.

5.2. Generalizing Media Types

CoAP defines a registry for combinations of an Internet Media Type ("MIME type") and a Content Encoding (e.g. some form of compression), enabling its compact encoding of this information in one or two bytes. Each entry in the registry defines a single, fixed set of media type parameters (as in ";charset=utf-8"), if any. This does not work well with media types that rely on more complex combinations of parameter settings. [I-D.doi-core-parameter-option] proposes to add an option to carry parameters for media types.

[I-D.fossati-core-multipart-ct] defines a new media type that can carry multiple embedded representations employing different media types using a binary type-length-value format.

5.3. Patience, Leisure, Pledge, or: Timing extensions

Several proposals intend to extend the amount of information available during an exchange about the timing requirements of the participants.

| draft-li-core-coap-patience-option | -01 | 2012-10-22 |

Another discussion is in Appendix B.4 of [I-D.bormann-coap-misc].

The question of whether some of this functionality should be introduced into the main WG documents now is currently also the subject of an active issue tracker ticket [CoRE204].

5.4. Extending Observe

5.5. Service discovery

Basic service discovery is defined in [RFC6690]. A JSON representation of the same information is defined in [I-D.ietf-core-links-json]. The intention is to make this information available in an equivalent format that is more accessible to classic Web servers, both as a file format (Internet media type) and as a format that can be used in e.g. a JavaScript API.

[I-D.arkko-core-dev-urn] defines a new Uniform Resource Name (URN) namespace that can be used to provide hardware device identifiers in resource descriptions.

[I-D.ietf-core-interfaces] provides additional semantics that can be used to make resource descriptions more directly machine-interpretable. This ties in to a more general discussion about CoRE profiles that has only just begun.

[I-D.greevenbosch-core-profile-description] ties into this and defines a basic JSON format for indicating what CoAP Options and what Content-Formats (still called media-types there) are available for a resource. At IETF86 there was fairly good consensus in the CoRE WG that we should be working on something addressing the underlying problem statement, while there was not yet agreement on the specific solution.

[I-D.fossati-core-fp-link-format-attribute] defines a link-format attribute that indicates a certain resource is best reached via a specific proxy.

5.6. Server discovery, Naming, etc.

On the boundary between service and server discovery, resource directory servers provide a way to collect resource descriptions from multiple servers into one accessible location.

[I-D.bormann-core-simple-server-discovery] provided a basic way to discover such servers in a constrained node/network without necessarily having to resort to multicast. It has been merged into [I-D.ietf-core-resource-directory], which defines protocol elements that can be used for setting up such a resource directory.

An attempt to merge mDNS/DNS-SD-based discovery (colloquially known as zeroconf or Bonjour), including recent approaches to extend these for constrained networks, into the picture is documented in [I-D.vanderstok-core-dna]; at IETF86 the authors showed interest to continue work on this.

5.7. More support for sleepy nodes

The basic communication model of CoAP was imported from the Web. This applies well to some communication requirements in constrained node/networks, but leaves some other requirements open.

The assumption underlying the current set of WG documents is that the communication layers below the application provide support functions for sleeping nodes. Adding support at the application layer might be able to further reduce the power requirements of "sleepy nodes" that can sleep most of the time.

[I-D.rahman-core-sleepy-problem-statement] summarizes the overall problem statement for sleepy nodes without getting into any specific solution.

A number of drafts aim to extend the CoAP communication model towards more support for sleepy nodes.

The base CoAP spec [I-D.ietf-core-coap] already provides some rudimentary support of sleepy nodes by supporting caching in intermediaries: resources from a sleepy node may be available from a caching proxy (if previously retrieved) even though the node is asleep. [I-D.ietf-core-observe] enhances this support by enabling sleepy nodes to update caching intermediaries on their own schedule.

A number of drafts more extensively extend the concept of an intermediary by introducing an additional kind of server that is hosting the resources of the sleepy node:

The approach of [I-D.vial-core-mirror-server] is to store the actual resource representations in a special type of Resource Directory called the Mirror Server. Communicating devices can then fetch the resource from the Mirror Server regardless of the state of the sleepy server. ([I-D.vial-core-mirror-proxy] simply appears to be a previous version of this draft.)

Similar to the above, the approach of [I-D.fossati-core-publish-option] is to temporarily delegate authority of its resources (when it is sleeping) to a proxy server that is always on.

Also, the approach of [I-D.giacomin-core-sleepy-option] is to define a proxy that acts as a store-and-forward agent for a sleepy node.

Other drafts introduce a variety of signaling based approaches to facilitate communicating with sleepy nodes: The approach of [I-D.castellani-core-alive] is to define a new CoAP message type (called "Alive") which the sleepy node multicasts to all interested devices when it wakes up. The approach of [I-D.rahman-core-sleepy] is to introduce storing of sleep characteristics in the Resource Directory. Communicating devices can then query the RD to learn the sleep status of the sleepy node before attempting communications.

Finally, some drafts build on the concept of the Observe mechanism to help keep track of the sleepy node information. The approach of [I-D.fossati-core-monitor-option] is to extend the Observe pattern to handle the scenario when both server and clients are sleepy nodes. Note that some of the other drafts (e.g., [I-D.vial-core-mirror-server], [I-D.rahman-core-sleepy]) include

using/extending the Observe mechanism as part of their overall approach.

Support for sleepy nodes is currently a very active subject of discussion in the WG; it is clear that there is a high level of interest in the WG in addressing application-level support for sleepy nodes in future specifications. See also the discussion of [I-D.ietf-lwig-cellular] in Section 3.1 above.

6. Replaced drafts

Internet-Drafts often get replaced by merged drafts or get promoted to WG drafts. As the relationships between drafts are not always accurately captured by the secretariat tools, this table provides a mapping from current drafts to any previous drafts they are replacing:

current draft	replaced draft
[I-D.ietf-core-coap]	draft-shelby-core-coap
[I-D.ietf-core-block]	draft-bormann-core-coap-block
	draft-li-core-coap-size-option
[I-D.ietf-core-observe]	draft-hartke-coap-observe
[RFC6690]	draft-shelby-core-link-format
[I-D.ietf-core-groupcomm]	draft-rahman-core-groupcomm
[I-D.becker-core-coap-sms-gprs]	draft-li-core-coap-over-sms
[I-D.vanderstok-core-dna]	draft-vanderstok-core-bc
[I-D.ietf-core-resource-directory]	draft-bormann-core-simple-server-discovery
[I-D.greevenbosch-core-minimum-request-interval]	draft-greevenbosch-core-block-minimum-time

Note that draft-scim-core-schema is just named against the naming conventions and actually unrelated to the CoRE working group.

7. IANA Considerations

This document has no actions for IANA.

8. Security Considerations

(None so far; this section will certainly grow as additional security considerations beyond those listed in the base specifications become known.)

9. Acknowledgements

(The concept for this document is borrowed from [RFC4815], which was invented by Lars-Erik Jonsson. Thanks!)

Akbar Rahman contributed text to this roadmap.

10. References

10.1. Normative References

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Author's Address

Carsten Bormann
Universitaet Bremen TZI
Postfach 330440
Bremen D-28359
Germany

Phone: +49-421-218-63921
Email: cabo@tzi.org