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C. Bormann
Universitaet Bremen TZI
Z. Shelby, Ed.
ARM

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Block-Wise Transfers in the Constrained Application Protocol (CoAP)

Abstract

The Constrained Application Protocol (CoAP) is a RESTful transfer protocol for constrained nodes and networks. Basic CoAP messages work well for small payloads from sensors and actuators; however, applications will need to transfer larger payloads occasionally -- for instance, for firmware updates. In contrast to HTTP, where TCP does the grunt work of segmenting and resequencing, CoAP is based on datagram transports such as UDP or Datagram Transport Layer Security (DTLS). These transports only offer fragmentation, which is even more problematic in constrained nodes and networks, limiting the maximum size of resource representations that can practically be transferred.

Instead of relying on IP fragmentation, this specification extends basic CoAP with a pair of "Block" options for transferring multiple blocks of information from a resource representation in multiple request-response pairs. In many important cases, the Block options enable a server to be truly stateless: the server can handle each block transfer separately, with no need for a connection setup or other server-side memory of previous block transfers. Essentially, the Block options provide a minimal way to transfer larger representations in a block-wise fashion.

A CoAP implementation that does not support these options generally is limited in the size of the representations that can be exchanged, so there is an expectation that the Block options will be widely used in CoAP implementations. Therefore, this specification updates RFC 7252.

Status of This Memo

This is an Internet Standards Track document.

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

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc7959.

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1. Introduction

The work on Constrained RESTful Environments (CoRE) aims at realizing the Representational State Transfer (REST) architecture in a suitable form for the most constrained nodes (such as microcontrollers with limited RAM and ROM [RFC7228]) and networks (such as IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs) [RFC4944]) [RFC7252]. The CoAP protocol is intended to provide RESTful [REST] services not unlike HTTP [RFC7230], while reducing the complexity of implementation as well as the size of packets exchanged in order to make these services useful in a highly constrained network of highly constrained nodes.

This objective requires restraint in a number of sometimes conflicting ways:

- reducing implementation complexity in order to minimize code size,
- reducing message sizes in order to minimize the number of fragments needed for each message (to maximize the probability of delivery of the message), the amount of transmission power needed, and the loading of the limited-bandwidth channel,
- reducing requirements on the environment such as stable storage, good sources of randomness, or user-interaction capabilities.

Because CoAP is based on datagram transports such as UDP or Datagram Transport Layer Security (DTLS), the maximum size of resource representations that can be transferred without too much fragmentation is limited. In addition, not all resource representations will fit into a single link-layer packet of a constrained network, which may cause adaptation layer fragmentation even if IP-layer fragmentation is not required. Using fragmentation (either at the adaptation layer or at the IP layer) for the transport of larger representations would be possible up to the maximum size of the underlying datagram protocol (such as UDP), but the fragmentation/reassembly process burdens the lower layers with conversation state that is better managed in the application layer.

The present specification defines a pair of CoAP options to enable block-wise access to resource representations. The Block options provide a minimal way to transfer larger resource representations in a block-wise fashion. The overriding objective is to avoid the need for creating conversation state at the server for block-wise GET requests. (It is impossible to fully avoid creating conversation state for POST/PUT, if the creation/replacement of resources is to be atomic; where that property is not needed, there is no need to create server conversation state in this case, either.)

Block-wise transfers are realized as combinations of exchanges, each of which is performed according to the CoAP base protocol [RFC7252]. Each exchange in such a combination is governed by the specifications in [RFC7252], including the congestion control specifications (Section 4.7 of [RFC7252]) and the security considerations (Section 11 of [RFC7252]; additional security considerations then apply to the transfers as a whole, see Section 7). The present specification minimizes the constraints it adds to those base exchanges; however, not all variants of using CoAP are very useful inside a block-wise transfer (e.g., using Non-confirmable requests within block-wise transfers outside the use case of Section 2.8 would escalate the overall non-delivery probability). To be perfectly clear, the present specification also does not remove any of the constraints posed by the base specification it is strictly layered on top of. For example, back-to-back packets are limited by the congestion control described in Section 4.7 of [RFC7252] (NSTART as a limit for initiating exchanges, PROBING_RATE as a limit for sending with no response); block-wise transfers cannot send/solicit more traffic than a client could be sending to / soliciting from the same server without the block-wise mode.

In some cases, the present specification will RECOMMEND that a client perform a sequence of block-wise transfers "without undue delay". This cannot be phrased as an interoperability requirement, but is an expectation on implementation quality. Conversely, the expectation is that servers will not have to go out of their way to accommodate clients that take considerable time to finish a block-wise transfer. For example, for a block-wise GET, if the resource changes while this proceeds, the entity-tag (ETag) for a further block obtained may be different. To avoid this happening all the time for a fast-changing resource, a server MAY try to keep a cache around for a specific client for a short amount of time. The expectation here is that the lifetime for such a cache can be kept short, on the order of a few expected round-trip times, counting from the previous block transferred.

In summary, this specification adds a pair of Block options to CoAP that can be used for block-wise transfers. Benefits of using these options include:

- Transfers larger than what can be accommodated in constrained-network link-layer packets can be performed in smaller blocks.

- No hard-to-manage conversation state is created at the adaptation layer or IP layer for fragmentation.

- The transfer of each block is acknowledged, enabling individual retransmission if required.

- Both sides have a say in the block size that actually will be used.

- The resulting exchanges are easy to understand using packet analyzer tools, and thus quite accessible to debugging.

- If needed, the Block options can also be used (without changes) to provide random access to power-of-two sized blocks within a resource representation.

A CoAP implementation that does not support these options generally is limited in the size of the representations that can be exchanged, see Section 4.6 of [RFC7252]. Even though the options are Critical, a server may decide to start using them in an unsolicited way in a response. No effort was expended to provide a capability indication mechanism supporting that decision: since the block-wise transfer mechanisms are so fundamental to the use of CoAP for representations larger than about a kilobyte, there is an expectation that they are very widely implemented.

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 RFC 2119, BCP 14 [RFC2119] and indicate requirement levels for compliant CoAP implementations.

In this document, the term "byte" is used in its now customary sense as a synonym for "octet".

Where bit arithmetic is explained, this document uses the notation familiar from the programming language C, except that the operator "**" stands for exponentiation.

2. Block-Wise Transfers

As discussed in the introduction, there are good reasons to limit the size of datagrams in constrained networks:

- by the maximum datagram size (~ 64 KiB for UDP)

- by the desire to avoid IP fragmentation (MTU of 1280 for IPv6)

- by the desire to avoid adaptation-layer fragmentation (60-80 bytes for 6LoWPAN [RFC4919])

When a resource representation is larger than can be comfortably transferred in the payload of a single CoAP datagram, a Block option can be used to indicate a block-wise transfer. As payloads can be

sent both with requests and with responses, this specification provides two separate options for each direction of payload transfer. In naming these options (for block-wise transfers as well as in Section 4), we use the number 1 ("Block1", "Size1") to refer to the transfer of the resource representation that pertains to the request, and the number 2 ("Block2", "Size2") to refer to the transfer of the resource representation for the response.

In the following, the term "payload" will be used for the actual content of a single CoAP message, i.e., a single block being transferred, while the term "body" will be used for the entire resource representation that is being transferred in a block-wise fashion. The Content-Format Option applies to the body, not to the payload; in particular, the boundaries between the blocks may be in places that are not separating whole units in terms of the structure, encoding, or content-coding used by the Content-Format. (Similarly, the ETag Option defined in Section 5.10.6 of [RFC7252] applies to the whole representation of the resource, and thus to the body of the response.)

In most cases, all blocks being transferred for a body (except for the last one) will be of the same size. (If the first request uses a bigger block size than the receiver prefers, subsequent requests will use the preferred block size.) The block size is not fixed by the protocol. To keep the implementation as simple as possible, the Block options support only a small range of power-of-two block sizes, from 2**4 (16) to 2**10 (1024) bytes. As bodies often will not evenly divide into the power-of-two block size chosen, the size need not be reached in the final block (but even for the final block, the chosen power-of-two size will still be indicated in the block size field of the Block option).

2.1. The Block2 and Block1 Options

No.	C	U	N	R	Name	Format	Length	Default
23	C	U	-	-	Block2	uint	0-3	(none)
27	C	U	-	-	Block1	uint	0-3	(none)

Table 1: Block Option Numbers

Both Block1 and Block2 Options can be present in both the request and response messages. In either case, the Block1 Option pertains to the request payload, and the Block2 Option pertains to the response payload.

Hence, for the methods defined in [RFC7252], Block1 is useful with the payload-bearing POST and PUT requests and their responses. Block2 is useful with GET, POST, and PUT requests and their payload-bearing responses (2.01, 2.02, 2.04, and 2.05 -- see Section 5.5 of [RFC7252]).

Where Block1 is present in a request or Block2 in a response (i.e., in that message to the payload of which it pertains) it indicates a block-wise transfer and describes how this specific block-wise payload forms part of the entire body being transferred ("descriptive usage"). Where it is present in the opposite direction, it provides additional control on how that payload will be formed or was processed ("control usage").

Implementation of either Block option is intended to be optional. However, when it is present in a CoAP message, it MUST be processed (or the message rejected); therefore, it is identified as a Critical option. Either Block option MUST NOT occur more than once in a single message.

2.2. Structure of a Block Option

Three items of information may need to be transferred in a Block (Block1 or Block2) option:

- the size of the block (SZX);
- whether more blocks are following (M);
- the relative number of the block (NUM) within a sequence of blocks with the given size.

The value of the Block option is a variable-size (0 to 3 byte) unsigned integer (uint, see Section 3.2 of [RFC7252]). This integer value encodes these three fields, see Figure 1. (Due to the CoAP uint-encoding rules, when all of NUM, M, and SZX happen to be zero, a zero-byte integer will be sent.)

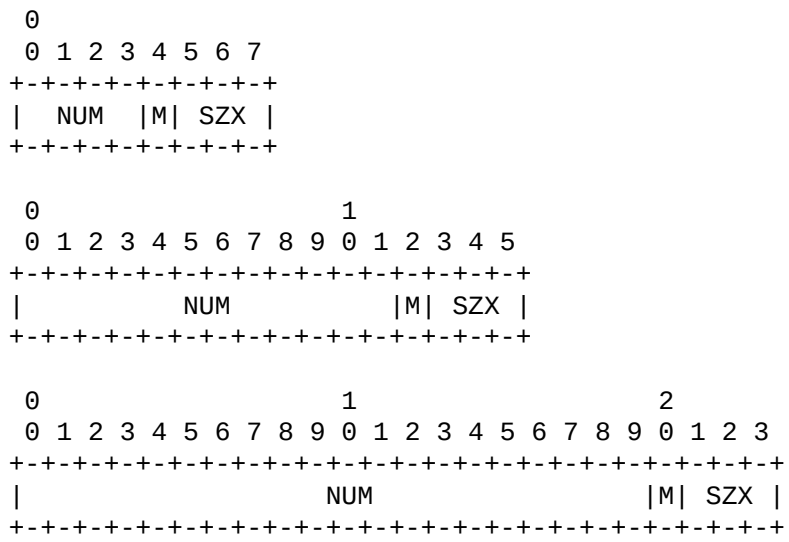


Figure 1: Block Option Value

The block size is encoded using a three-bit unsigned integer (0 for 2**4 bytes to 6 for 2**10 bytes), which we call the "SZX" ("size exponent"); the actual block size is then "2**(SZX + 4)". SZX is transferred in the three least significant bits of the option value (i.e., "val & 7" where "val" is the value of the option).

The fourth least significant bit, the M or "more" bit ("val & 8"), indicates whether more blocks are following or if the current block-wise transfer is the last block being transferred.

The option value divided by sixteen (the NUM field) is the sequence number of the block currently being transferred, starting from zero. The current transfer is, therefore, about the "size" bytes starting at byte "NUM << (SZX + 4)".

Implementation note: As an implementation convenience, "(val & ~0xF) << (val & 7)", i.e., the option value with the last 4 bits masked out, shifted to the left by the value of SZX, gives the byte position of the first byte of the block being transferred.

More specifically, within the option value of a Block1 or Block2 Option, the meaning of the option fields is defined as follows:

NUM: Block Number, indicating the block number being requested or provided. Block number 0 indicates the first block of a body (i.e., starting with the first byte of the body).

M: More Flag ("not last block"). For descriptive usage, this flag, if unset, indicates that the payload in this message is the last block in the body; when set, it indicates that there are one or more additional blocks available. When a Block2 Option is used in a request to retrieve a specific block number ("control usage"), the M bit MUST be sent as zero and ignored on reception. (In a Block1 Option in a response, the M flag is used to indicate atomicity, see below.)

SZX: Block Size. The block size is represented as a three-bit unsigned integer indicating the size of a block to the power of two. Thus, block size = 2**(SZX + 4). The allowed values of SZX are 0 to 6, i.e., the minimum block size is 2**(0+4) = 16 and the maximum is 2**(6+4) = 1024. The value 7 for SZX (which would indicate a block size of 2048) is reserved, i.e., MUST NOT be sent and MUST lead to a 4.00 Bad Request response code upon reception in a request.

There is no default value for the Block1 and Block2 Options. Absence of one of these options is equivalent to an option value of 0 with respect to the value of NUM and M that could be given in the option, i.e., it indicates that the current block is the first and only block of the transfer (block number 0, M bit not set). However, in contrast to the explicit value 0, which would indicate an SZX of 0 and thus a size value of 16 bytes, there is no specific explicit size implied by the absence of the option -- the size is left unspecified. (As for any uint, the explicit value 0 is efficiently indicated by a zero-length option; this, therefore, is different in semantics from the absence of the option.)

2.3. Block Options in Requests and Responses

The Block options are used in one of three roles:

- In descriptive usage, i.e., a Block2 Option in a response (such as a 2.05 response for GET), or a Block1 Option in a request (a PUT or POST):
  - The NUM field in the option value describes what block number is contained in the payload of this message.
  - The M bit indicates whether further blocks need to be transferred to complete the transfer of that body.
  - The block size implied by SZX MUST match the size of the payload in bytes, if the M bit is set. (SZX does not govern the payload size if M is unset). For Block2, if the request suggested a larger value of SZX, the next request MUST move SZX

down to the size given in the response. (The effect is that, if the server uses the smaller of (1) its preferred block size and (2) the block size requested, all blocks for a body use the same block size.)

- A Block2 Option in control usage in a request (e.g., GET):
  - The NUM field in the Block2 Option gives the block number of the payload that is being requested to be returned in the response.
  - In this case, the M bit has no function and MUST be set to zero.
  - The block size given (SZX) suggests a block size (in the case of block number 0) or repeats the block size of previous blocks received (in the case of a non-zero block number).
- A Block1 Option in control usage in a response (e.g., a 2.xx response for a PUT or POST request):
  - The NUM field of the Block1 Option indicates what block number is being acknowledged.
  - If the M bit was set in the request, the server can choose whether to act on each block separately, with no memory, or whether to handle the request for the entire body atomically, or any mix of the two.
    - If the M bit is also set in the response, it indicates that this response does not carry the final response code to the request, i.e., the server collects further blocks from the same endpoint and plans to implement the request atomically (e.g., acts only upon reception of the last block of payload). In this case, the response MUST NOT carry a Block2 Option.
    - Conversely, if the M bit is unset even though it was set in the request, it indicates the block-wise request was enacted now specifically for this block, and the response carries the final response to this request (and to any previous ones with the M bit set in the response's Block1 Option in this sequence of block-wise transfers); the client is still expected to continue sending further blocks, the request method for which may or may not also be enacted per-block. (Note that the resource is now in a partially updated state; this approach is only appropriate where exposing such an

intermediate state is acceptable. The client can reduce the window by quickly continuing to update the resource, or, in case of failure, restarting the update.)

* Finally, the SZX block size given in a control Block1 Option indicates the largest block size preferred by the server for transfers toward the resource that is the same or smaller than the one used in the initial exchange; the client SHOULD use this block size or a smaller one in all further requests in the transfer sequence, even if that means changing the block size (and possibly scaling the block number accordingly) from now on.

Using one or both Block options, a single REST operation can be split into multiple CoAP message exchanges. As specified in [RFC7252], each of these message exchanges uses their own CoAP Message ID.

The Content-Format Option sent with the requests or responses MUST reflect the Content-Format of the entire body. If blocks of a response body arrive with different Content-Format Options, it is up to the client how to handle this error (it will typically abort any ongoing block-wise transfer). If blocks of a request arrive at a server with mismatching Content-Format Options, the server MUST NOT assemble them into a single request; this usually leads to a 4.08 (Request Entity Incomplete, Section 2.9.2) error response on the mismatching block.

2.4. Using the Block2 Option

When a request is answered with a response carrying a Block2 Option with the M bit set, the requester may retrieve additional blocks of the resource representation by sending further requests with the same options as the initial request and a Block2 Option giving the block number and block size desired. In a request, the client MUST set the M bit of a Block2 Option to zero and the server MUST ignore it on reception.

To influence the block size used in a response, the requester MAY also use the Block2 Option on the initial request, giving the desired size, a block number of zero and an M bit of zero. A server MUST use the block size indicated or a smaller size. Any further block-wise requests for blocks beyond the first one MUST indicate the same block size that was used by the server in the response for the first request that gave a desired size using a Block2 Option.

Once the Block2 Option is used by the requester and a first response has been received with a possibly adjusted block size, all further requests in a single block-wise transfer will ultimately converge on

using the same size, except that there may not be enough content to fill the last block (the one returned with the M bit not set). (Note that the client may start using the Block2 Option in a second request after a first request without a Block2 Option resulted in a Block2 Option in the response.) The server uses the block size indicated in the request option or a smaller size, but the requester MUST take note of the actual block size used in the response it receives to its initial request and proceed to use it in subsequent requests. The server behavior MUST ensure that this client behavior results in the same block size for all responses in a sequence (except for the last one with the M bit not set, and possibly the first one if the initial request did not contain a Block2 Option).

Block-wise transfers can be used to GET resources whose representations are entirely static (not changing over time at all, such as in a schema describing a device), or for dynamically changing resources. In the latter case, the Block2 Option SHOULD be used in conjunction with the ETag Option ([RFC7252], Section 5.10.6), to ensure that the blocks being reassembled are from the same version of the representation: The server SHOULD include an ETag Option in each response. If an ETag Option is available, the client, when reassembling the representation from the blocks being exchanged, MUST compare ETag Options. If the ETag Options do not match in a GET transfer, the requester has the option of attempting to retrieve fresh values for the blocks it retrieved first. To minimize the resulting inefficiency, the server MAY cache the current value of a representation for an ongoing sequence of requests. (The server may identify the sequence by the combination of the requesting endpoint and the URI being the same in each block-wise request.) Note well that this specification makes no requirement for the server to establish any state; however, servers that offer quickly changing resources may thereby make it impossible for a client to ever retrieve a consistent set of blocks. Clients that want to retrieve all blocks of a resource SHOULD strive to do so without undue delay. Servers can fully expect to be free to discard any cached state after a period of EXCHANGE_LIFETIME ([RFC7252], Section 4.8.2) after the last access to the state, however, there is no requirement to always keep the state for as long.

The Block2 Option provides no way for a single endpoint to perform multiple concurrently proceeding block-wise response payload transfer (e.g., GET) operations to the same resource. This is rarely a requirement, but as a workaround, a client may vary the cache key (e.g., by using one of several URIs accessing resources with the same semantics, or by varying a proxy-safe elective option).

2.5. Using the Block1 Option

In a request with a request payload (e.g., PUT or POST), the Block1 Option refers to the payload in the request (descriptive usage).

In response to a request with a payload (e.g., a PUT or POST transfer), the block size given in the Block1 Option indicates the block size preference of the server for this resource (control usage). Obviously, at this point the first block has already been transferred by the client without benefit of this knowledge. Still, the client SHOULD heed the preference indicated and, for all further blocks, use the block size preferred by the server or a smaller one. Note that any reduction in the block size may mean that the second request starts with a block number larger than one, as the first request already transferred multiple blocks as counted in the smaller size.

To counter the effects of adaptation-layer fragmentation on packet-delivery probability, a client may want to give up retransmitting a request with a relatively large payload even before MAX_RETRANSMIT has been reached, and try restating the request as a block-wise transfer with a smaller payload. Note that this new attempt is then a new message-layer transaction and requires a new Message ID. (Because of the uncertainty about whether the request or the acknowledgement was lost, this strategy is useful mostly for idempotent requests.)

In a block-wise transfer of a request payload (e.g., a PUT or POST) that is intended to be implemented in an atomic fashion at the server, the actual creation/replacement takes place at the time the final block, i.e., a block with the M bit unset in the Block1 Option, is received. In this case, all success responses to non-final blocks carry the response code 2.31 (Continue, Section 2.9.1). If not all previous blocks are available at the server at the time of processing the final block, the transfer fails and error code 4.08 (Request Entity Incomplete, Section 2.9.2) MUST be returned. A server MAY also return a 4.08 error code for any (final or non-final) Block1 transfer that is not in sequence; therefore, clients that do not have specific mechanisms to handle this case SHOULD always start with block zero and send the following blocks in order.

One reason that a client might encounter a 4.08 error code is that the server has already timed out and discarded the partial request body being assembled. Clients SHOULD strive to send all blocks of a request without undue delay. Servers can fully expect to be free to discard any partial request body when a period of EXCHANGE_LIFETIME

([RFC7252], Section 4.8.2) has elapsed after the most recent block was transferred; however, there is no requirement on a server to always keep the partial request body for as long.

The error code 4.13 (Request Entity Too Large) can be returned at any time by a server that does not currently have the resources to store blocks for a block-wise request payload transfer that it would intend to implement in an atomic fashion. (Note that a 4.13 response to a request that does not employ Block1 is a hint for the client to try sending Block1, and a 4.13 response with a smaller SZX in its Block1 Option than requested is a hint to try a smaller SZX.)

A block-wise transfer of a request payload that is implemented in a stateless fashion at the server is likely to leave the resource being operated on in an inconsistent state while the transfer is still ongoing or when the client does not complete the transfer. This characteristic is closer to that of remote file systems than to that of HTTP, where state is always kept on the server during a transfer. Techniques well known from shared file access (e.g., client-specific temporary resources) can be used to mitigate this difference from HTTP.

The Block1 Option provides no way for a single endpoint to perform multiple concurrently proceeding block-wise request payload transfer (e.g., PUT or POST) operations to the same resource. Starting a new block-wise sequence of requests to the same resource (before an old sequence from the same endpoint was finished) simply overwrites the context the server may still be keeping. (This is probably exactly what one wants in this case -- the client may simply have restarted and lost its knowledge of the previous sequence.)

2.6. Combining Block-Wise Transfers with the Observe Option

The Observe option provides a way for a client to be notified about changes over time of a resource [RFC7641]. Resources observed by clients may be larger than can be comfortably processed or transferred in one CoAP message. The following rules apply to the combination of block-wise transfers with notifications.

Observation relationships always apply to an entire resource; the Block2 Option does not provide a way to observe a single block of a resource.

As with basic GET transfers, the client can indicate its desired block size in a Block2 Option in the GET request establishing or renewing the observation relationship. If the server supports block-wise transfers, it SHOULD take note of the block size and apply it as a maximum size to all notifications/responses resulting from the GET

request (until the client is removed from the list of observers or the entry in that list is updated by the server receiving a new GET request for the resource from the client).

When sending a 2.05 (Content) notification, the server only sends the first block of the representation. The client retrieves the rest of the representation as if it had caused this first response by a GET request, i.e., by using additional GET requests with Block2 Options containing NUM values greater than zero. (This results in the transfer of the entire representation, even if only some of the blocks have changed with respect to a previous notification.)

As with other dynamically changing resources, to ensure that the blocks being reassembled are from the same version of the representation, the server SHOULD include an ETag Option in each response, and the reassembling client MUST compare the ETag Options (Section 2.4). Even more so than for the general case of Block2, clients that want to retrieve all blocks of a resource they have been notified about with a first block SHOULD strive to do so without undue delay.

See Section 3.4 for examples.

2.7. Combining Block1 and Block2

In PUT and particularly in POST exchanges, both the request body and the response body may be large enough to require the use of block-wise transfers. First, the Block1 transfer of the request body proceeds as usual. In the exchange of the last slice of this block-wise transfer, the response carries the first slice of the Block2 transfer (NUM is zero). To continue this Block2 transfer, the client continues to send requests similar to the requests in the Block1 phase, but leaves out the Block1 Options and includes a Block2 request option with non-zero NUM.

Block2 transfers that retrieve the response body for a request that used Block1 MUST be performed in sequential order.

2.8. Combining Block2 with Multicast

A client can use the Block2 Option in a multicast GET request with NUM = 0 to aid in limiting the size of the response.

Similarly, a response to a multicast GET request can use a Block2 Option with NUM = 0 if the representation is large, or to further limit the size of the response.

In both cases, the client retrieves any further blocks using unicast exchanges; in the unicast requests, the client SHOULD heed any block size preferences indicated by the server in the response to the multicast request.

Other uses of the Block options in conjunction with multicast messages are for further study.

2.9. Response Codes

Beyond the response codes defined in [RFC7252], this specification defines two response codes and extends the meaning of one.

2.9.1. 2.31 Continue

This new success status code indicates that the transfer of this block of the request body was successful and that the server encourages sending further blocks, but that a final outcome of the whole block-wise request cannot yet be determined. No payload is returned with this response code.

2.9.2. 4.08 Request Entity Incomplete

This new client error status code indicates that the server has not received the blocks of the request body that it needs to proceed. The client has not sent all blocks, not sent them in the order required by the server, or has sent them long enough ago that the server has already discarded them.

(Note that one reason for not having the necessary blocks at hand may be a Content-Format mismatch, see Section 2.3. Implementation note: A server can reject a Block1 transfer with this code when NUM != 0 and a different Content-Format is indicated than expected from the current state of the resource. If it implements the transfer in a stateless fashion, it can match up the Content-Format of the block against that of the existing resource. If it implements the transfer in an atomic fashion, it can match up the block against the partially reassembled piece of representation that is going to replace the state of the resource.)

2.9.3. 4.13 Request Entity Too Large

In Section 5.9.2.9 of [RFC7252], the response code 4.13 (Request Entity Too Large) is defined to be like HTTP 413 "Request Entity Too Large". [RFC7252] also recommends that this response SHOULD include a Size1 Option (Section 4) to indicate the maximum size of request entity the server is able and willing to handle, unless the server is not in a position to make this information available.

The present specification allows the server to return this response code at any time during a Block1 transfer to indicate that it does not currently have the resources to store blocks for a transfer that it would intend to implement in an atomic fashion. It also allows the server to return a 4.13 response to a request that does not employ Block1 as a hint for the client to try sending Block1. Finally, a 4.13 response to a request with a Block1 Option (control usage, see Section 2.3) where the response carries a smaller SZX in its Block1 Option is a hint to try that smaller SZX.

2.10. Caching Considerations

This specification attempts to leave a variety of implementation strategies open for caches, in particular those in caching proxies. For example, a cache is free to cache blocks individually, but also could wait to obtain the complete representation before it serves parts of it. Partial caching may be more efficient in a cross-proxy (equivalent to a streaming HTTP proxy). A cached block (partial cached response) can be used in place of a complete response to satisfy a block-wise request that is presented to a cache. Note that different blocks can have different Max-Age values, as they are transferred at different times. A response with a block updates the freshness of the complete representation. Individual blocks can be validated, and validating a single block validates the complete representation. A response with a Block1 Option in control usage with the M bit set invalidates cached responses for the target URI.

A cache or proxy that combines responses (e.g., to split blocks in a request or increase the block size in a response, or a cross-proxy) may need to combine 2.31 and 2.01/2.04 responses; a stateless server may be responding with 2.01 only on the first Block1 block transferred, which dominates any 2.04 responses for later blocks.

If-None-Match only works correctly on Block1 requests with (NUM=0) and MUST NOT be used on Block1 requests with NUM != 0.

3. Examples

This section gives a number of short examples with message flows for a block-wise GET, and for a PUT or POST. These examples demonstrate the basic operation, the operation in the presence of retransmissions, and examples for the operation of the block size negotiation.

In all these examples, a Block option is shown in a decomposed way indicating the kind of Block option (1 or 2) followed by a colon, and then the block number (NUM), more bit (M), and block size exponent (2**(SZX+4)) separated by slashes. For example, a Block2 Option value of 33 would be shown as 2:2/0/32) and a Block1 Option value of 59 would be shown as 1:3/1/128.

As in [RFC7252], "MID" is used as an abbreviation for "Message ID".

3.1. Block2 Examples

The first example (Figure 2) shows a GET request that is split into three blocks. The server proposes a block size of 128, and the client agrees. The first two ACKs contain a payload of 128 bytes each, and the third ACK contains a payload between 1 and 128 bytes.

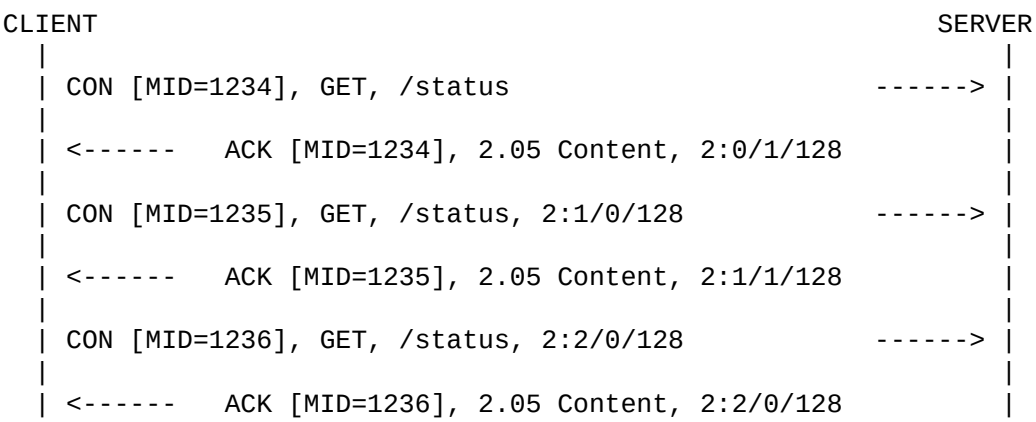


Figure 2: Simple Block-Wise GET

In the second example (Figure 3), the client anticipates the block-wise transfer (e.g., because of a size indication in the link-format description [RFC6690]) and sends a block size proposal. All ACK messages except for the last carry 64 bytes of payload; the last one carries between 1 and 64 bytes.

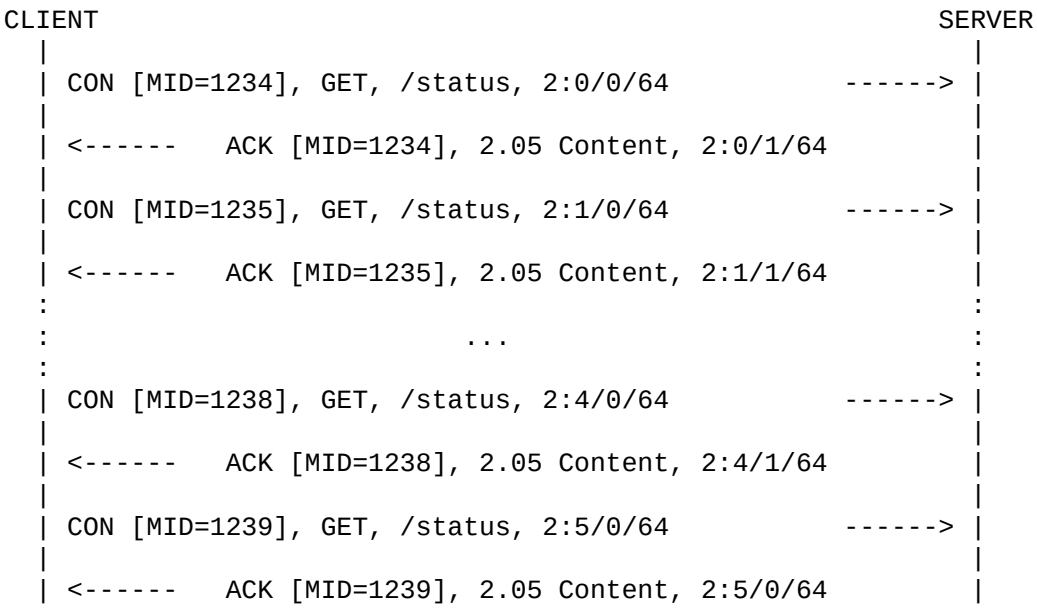


Figure 3: Block-Wise GET with Early Negotiation

In the third example (Figure 4), the client is surprised by the need for a block-wise transfer, and unhappy with the size chosen unilaterally by the server. As it did not send a size proposal initially, the negotiation only influences the size from the second message exchange onward. Since the client already obtained both the first and second 64-byte block in the first 128-byte exchange, it goes on requesting the third 64-byte block ("2/0/64"). None of this is (or needs to be) understood by the server, which simply responds to the requests as it best can.

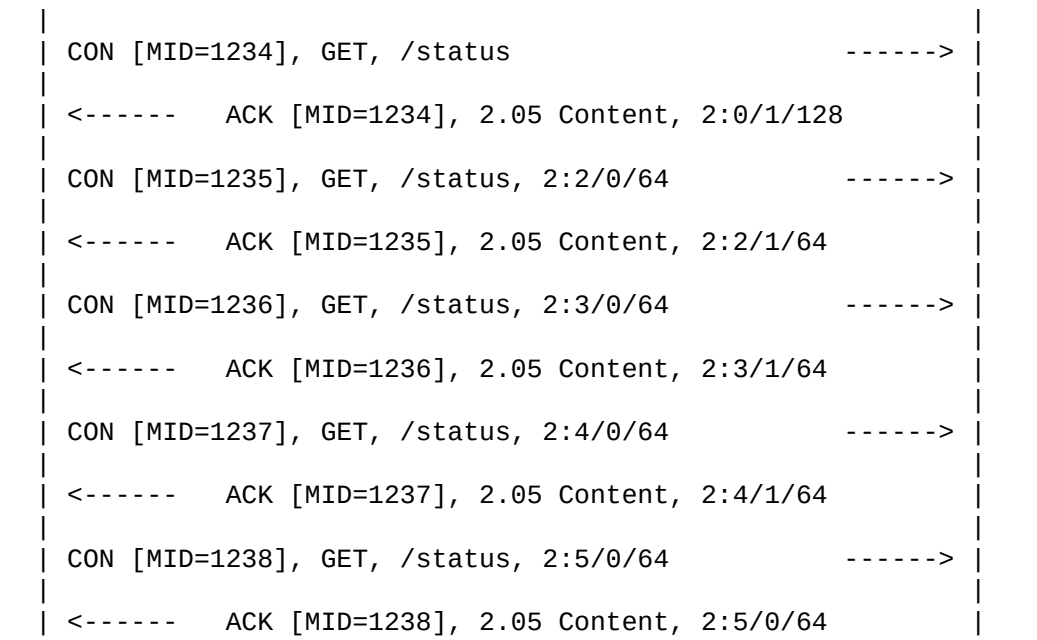


Figure 4: Block-Wise GET with Late Negotiation

In all these (and the following) cases, retransmissions are handled by the CoAP message exchange layer, so they don't influence the block operations (Figures 5 and 6).

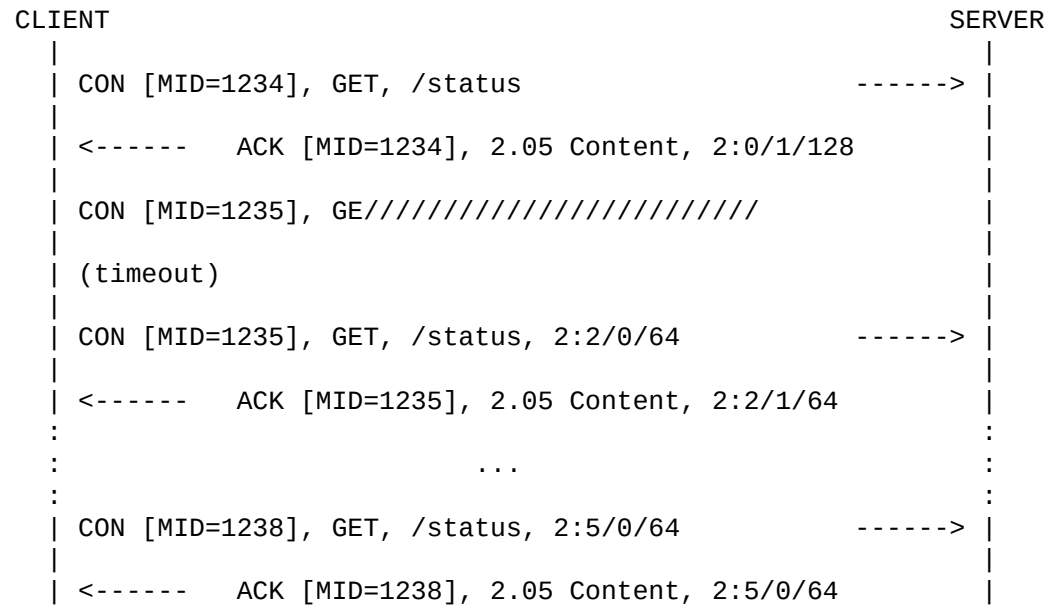


Figure 5: Block-Wise GET with Late Negotiation and Lost CON

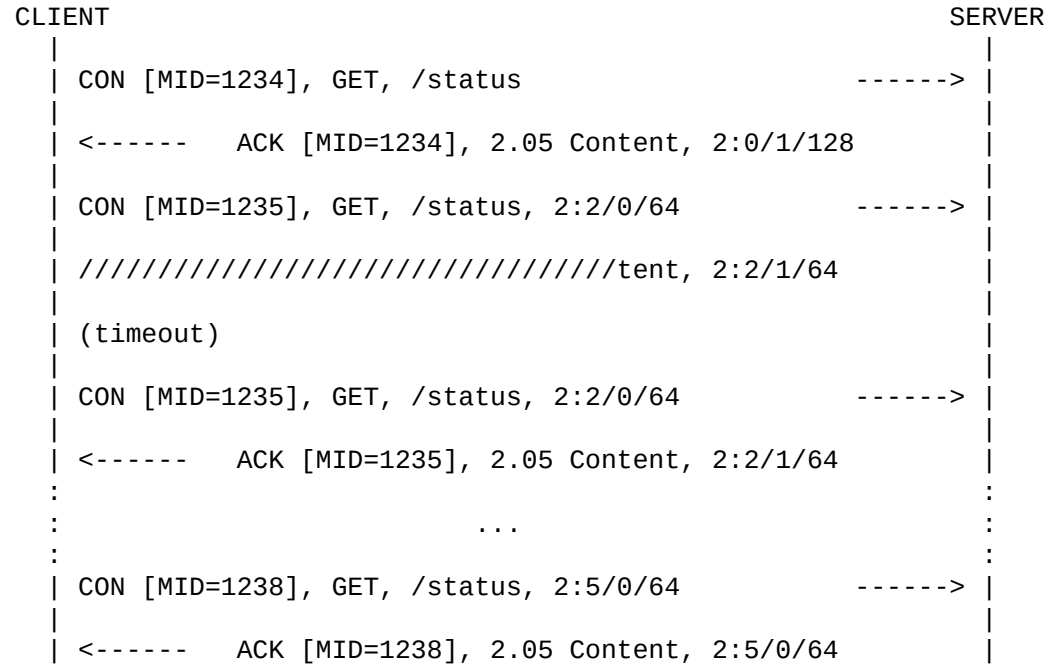


Figure 6: Block-Wise GET with Late Negotiation and Lost ACK

3.2. Block1 Examples

The following examples demonstrate a PUT exchange; a POST exchange looks the same, with different requirements on atomicity/idempotence. Note that, similar to GET, the responses to the requests that have a more bit in the request Block1 Option are provisional and carry the response code 2.31 (Continue); only the final response tells the client that the PUT succeeded.

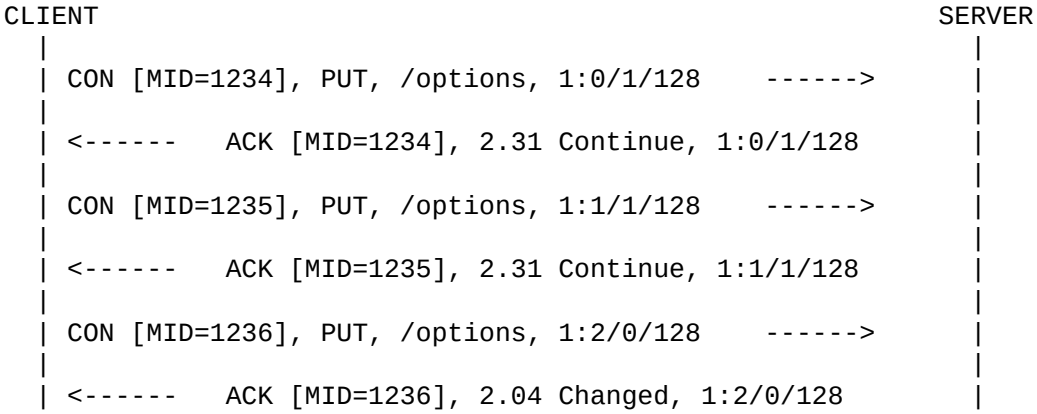


Figure 7: Simple Atomic Block-Wise PUT

A stateless server that simply builds/updates the resource in place (statelessly) may indicate this by not setting the more bit in the response (Figure 8); in this case, the response codes are valid separately for each block being updated. This is of course only an acceptable behavior of the server if the potential inconsistency present during the run of the message exchange sequence does not lead to problems, e.g., because the resource being created or changed is not yet or not currently in use.

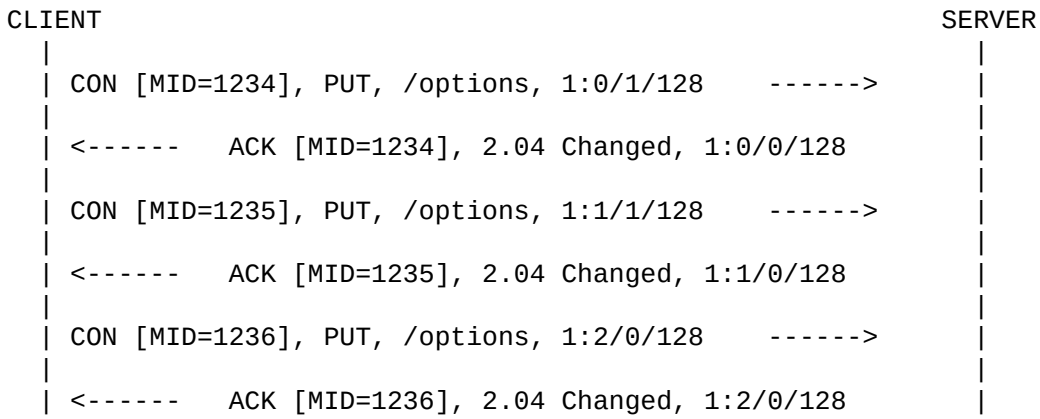


Figure 8: Simple Stateless Block-Wise PUT

Finally, a server receiving a block-wise PUT or POST may want to indicate a smaller block size preference (Figure 9). In this case, the client SHOULD continue with a smaller block size; if it does, it MUST adjust the block number to properly count in that smaller size.

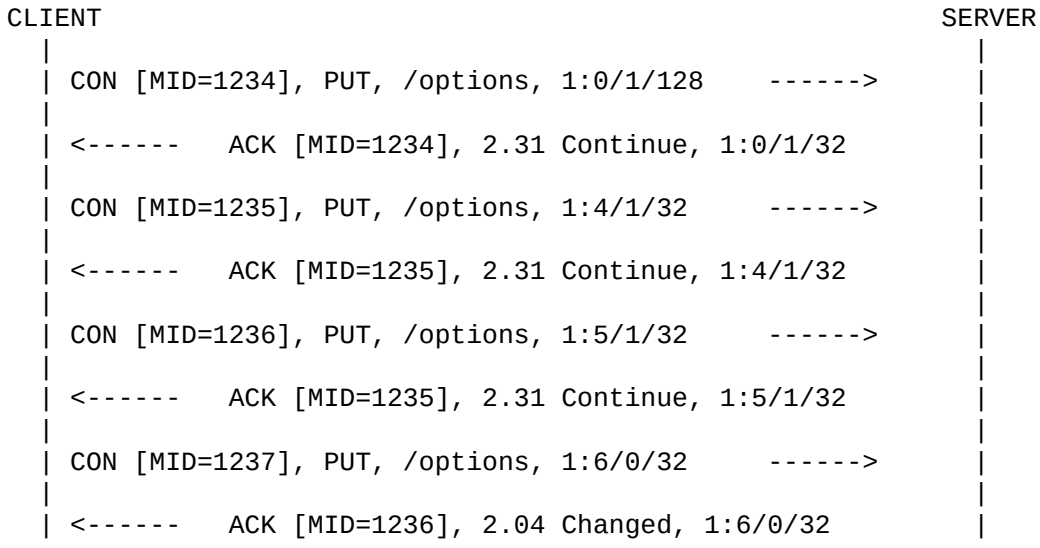


Figure 9: Simple Atomic Block-Wise PUT with Negotiation

3.3. Combining Block1 and Block2

Block options may be used in both directions of a single exchange. The following example demonstrates a block-wise POST request, resulting in a separate block-wise response.

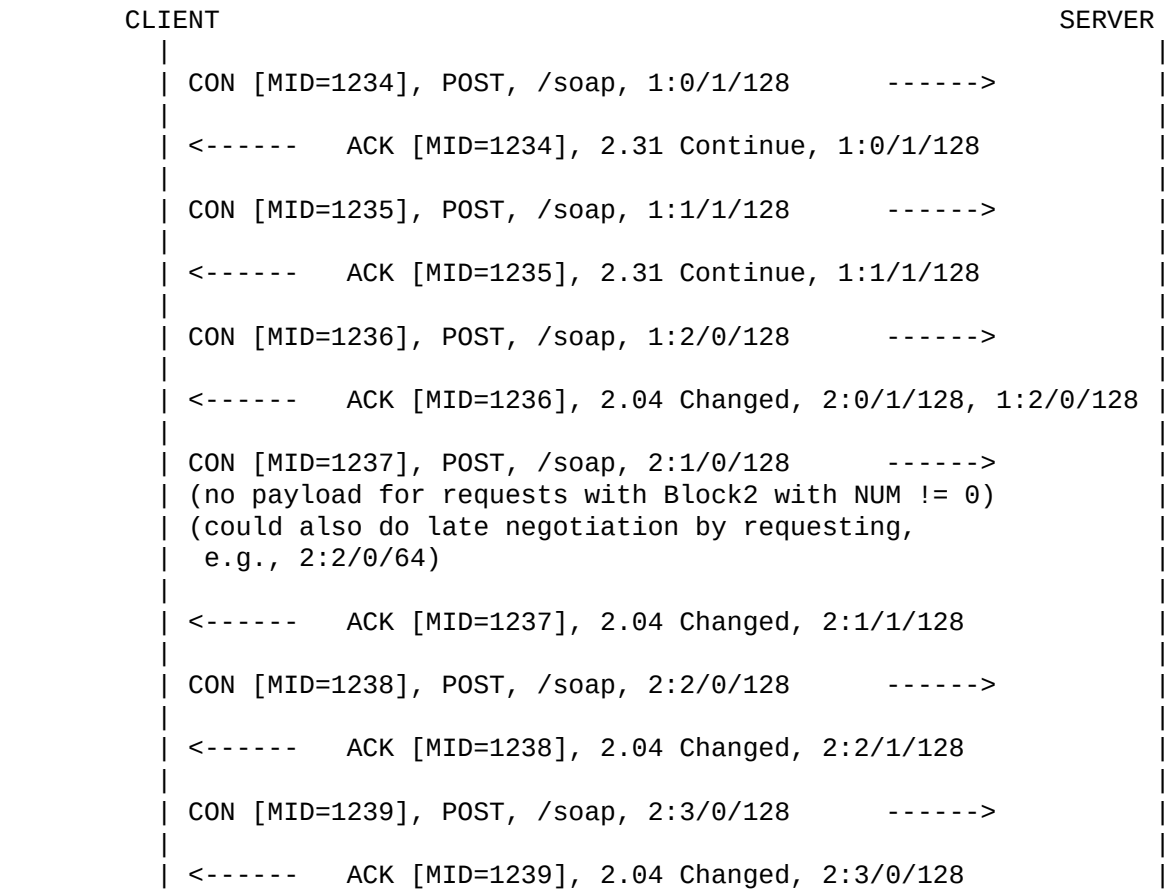


Figure 10: Atomic Block-Wise POST with Block-Wise Response

This model does provide for early negotiation input to the Block2 block-wise transfer, as shown below.

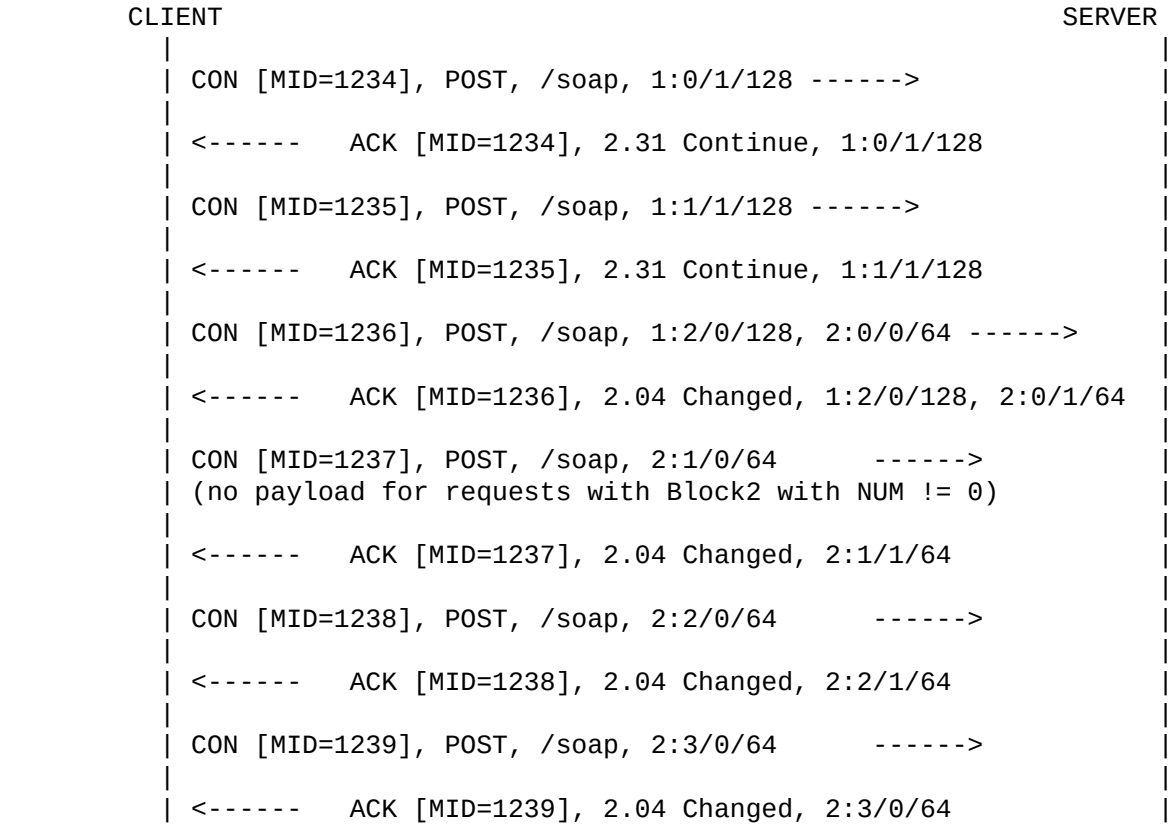
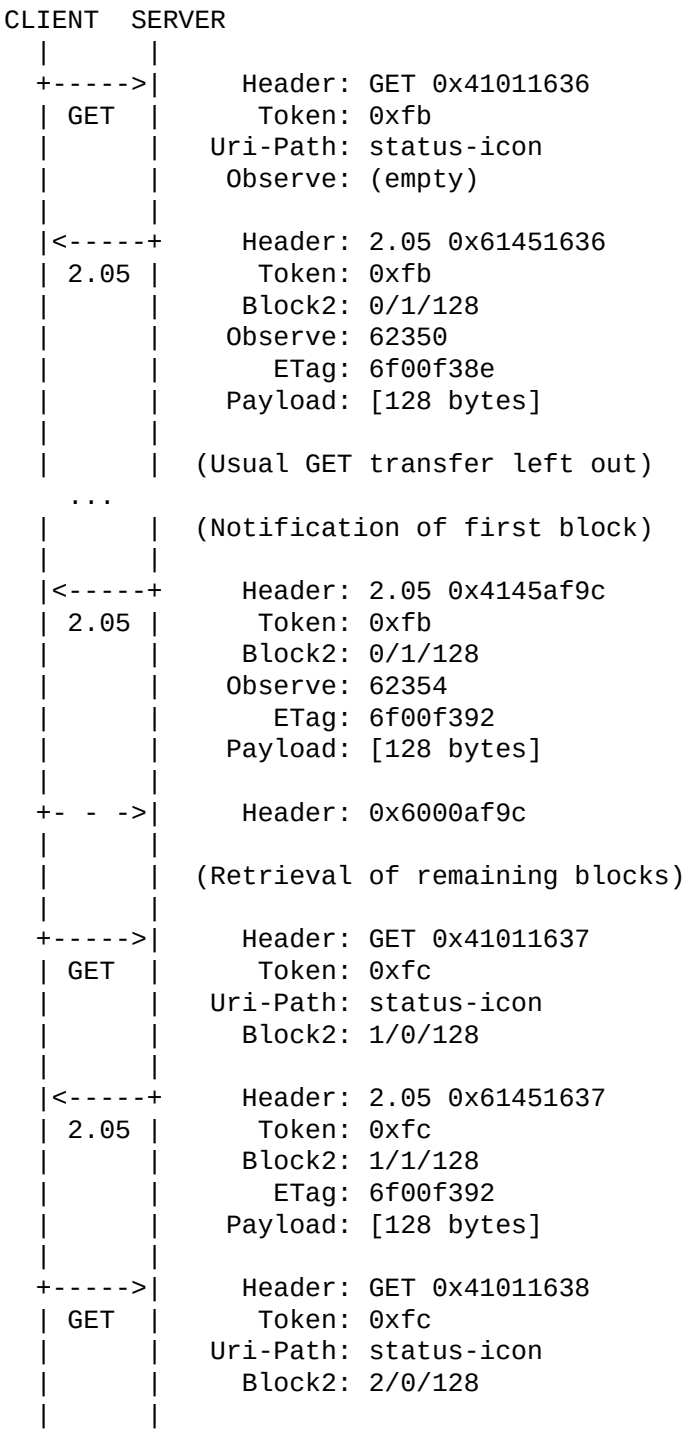


Figure 11: Atomic Block-Wise POST with Block-Wise Response, Early Negotiation

3.4. Combining Observe and Block2

In the following example, the server first sends a direct response (Observe sequence number 62350) to the initial GET request (the resulting block-wise transfer is as in Figure 4 and has therefore been left out). The second transfer is started by a 2.05 notification that contains just the first block (Observe sequence number 62354); the client then goes on to obtain the rest of the blocks.


CLIENT SERVER
GET
Header: GET 0x41011636
Token: 0xfb
Uri-Path: status-icon
Observe: (empty)
2.05
Header: 2.05 0x61451636
Token: 0xfb
Block2: 0/1/128
Observe: 62350
ETag: 6f00f38e
Payload: [128 bytes]
(Usual GET transfer left out)
...
(Notification of first block)
2.05
Header: 2.05 0x4145af9c
Token: 0xfb
Block2: 0/1/128
Observe: 62354
ETag: 6f00f392
Payload: [128 bytes]
Header: 0x6000af9c
(Retrieval of remaining blocks)
GET
Header: GET 0x41011637
Token: 0xfc
Uri-Path: status-icon
Block2: 1/0/128
2.05
Header: 2.05 0x61451637
Token: 0xfc
Block2: 1/1/128
ETag: 6f00f392
Payload: [128 bytes]
GET
Header: GET 0x41011638
Token: 0xfc
Uri-Path: status-icon
Block2: 2/0/128

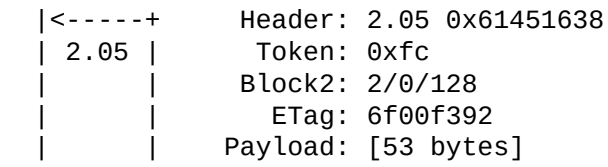
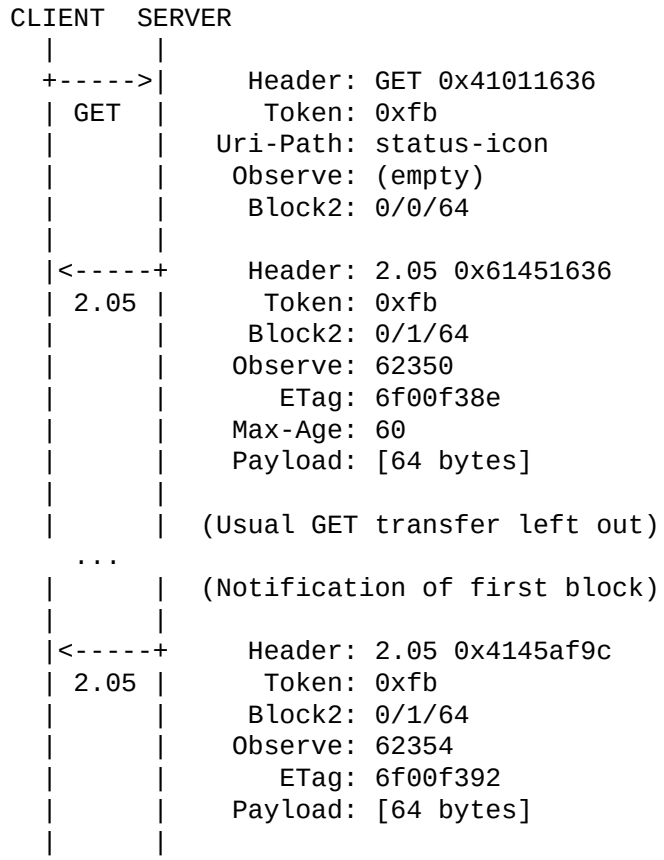


Figure 12: Observe Sequence with Block-Wise Response

(Note that the choice of token 0xfc in this example is arbitrary; tokens are just shown in this example to illustrate that the requests for additional blocks cannot make use of the token of the Observation relationship. As a general comment on tokens, there is no other mention of tokens in this document, as block-wise transfers handle tokens like any other CoAP exchange. As usual, the client is free to choose tokens for each exchange as it likes.)

In the following example, the client also uses early negotiation to limit the block size to 64 bytes.



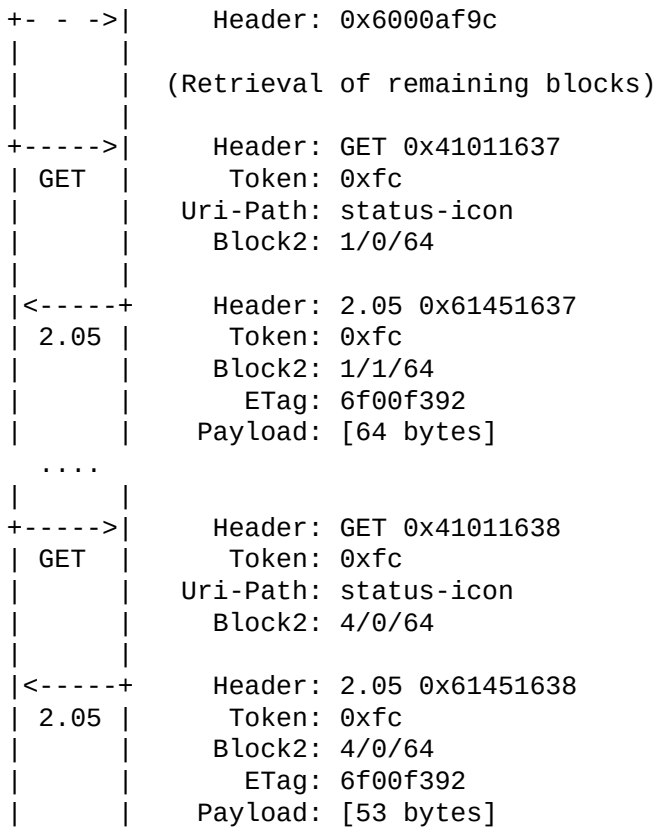


Figure 13: Observe Sequence with Early Negotiation

4. The Size2 and Size1 Options

In many cases when transferring a large resource representation block by block, it is advantageous to know the total size early in the process. Some indication may be available from the maximum size estimate attribute "sz" provided in a resource description [RFC6690]. However, the size may vary dynamically, so a more up-to-date indication may be useful.

This specification defines two CoAP options, Size1 for indicating the size of the representation transferred in requests, and Size2 for indicating the size of the representation transferred in responses. (Size1 has already been defined in Section 5.10.9 of [RFC7252] to provide "size information about the resource representation in a request"; however, that section only details the narrow case of indicating in 4.13 responses the maximum size of request payload that the server is able and willing to handle. The present specification provides details about its use as a request option as well.)

The Size2 Option may be used for two purposes:

- In a request, to ask the server to provide a size estimate along with the usual response ("size request"). For this usage, the value MUST be set to 0.

- In a response carrying a Block2 Option, to indicate the current estimate the server has of the total size of the resource representation, measured in bytes ("size indication").

Similarly, the Size1 Option may be used for two purposes:

- In a request carrying a Block1 Option, to indicate the current estimate the client has of the total size of the resource representation, measured in bytes ("size indication").

- In a 4.13 response, to indicate the maximum size that would have been acceptable [RFC7252], measured in bytes.

Apart from conveying/asking for size information, the Size options have no other effect on the processing of the request or response. If the client wants to minimize the size of the payload in the resulting response, it should add a Block2 Option to the request with a small block size (e.g., setting SZX=0).

The Size options are "elective", i.e., a client MUST be prepared for the server to ignore the size estimate request. Either Size option MUST NOT occur more than once in a single message.

No.	C	U	N	R	Name	Format	Length	Default
60			x		Size1	uint	0-4	(none)
28			x		Size2	uint	0-4	(none)

Table 2: Size Option Numbers

Implementation Notes:

- As a quality of implementation consideration, block-wise transfers for which the total size considerably exceeds the size of one block are expected to include size indications, whenever those can be provided without undue effort (preferably with the first block exchanged). If the size estimate does not change, the indication does not need to be repeated for every block.

- The end of a block-wise transfer is governed by the M bits in the Block options, _not_ by exhausting the size estimates exchanged.

- As usual for an option of type uint, the value 0 is best expressed as an empty option (0 bytes). There is no default value for either Size option.

- The Size options are neither critical nor unsafe, and are marked as No-Cache-Key.

5. HTTP-Mapping Considerations

In this subsection, we give some brief examples of the influence that the Block options might have on intermediaries that map between CoAP and HTTP.

For mapping CoAP requests to HTTP, the intermediary may want to map the sequence of block-wise transfers into a single HTTP transfer. For example, for a GET request, the intermediary could perform the HTTP request once the first block has been requested and could then fulfill all further block requests out of its cache. A constrained implementation may not be able to cache the entire object and may use a combination of TCP flow control and (in particular if timeouts occur) HTTP range requests to obtain the information necessary for the next block transfer at the right time.

For PUT or POST requests, historically there was more variation in how HTTP servers might implement ranges; recently, [RFC7233] has defined that Range header fields received with a request method other than GET are not to be interpreted. So, in general, the CoAP-to-HTTP intermediary will have to try sending the payload of all the blocks of a block-wise transfer for these other methods within one HTTP request. If enough buffering is available, this request can be started when the last CoAP block is received. A constrained implementation may want to relieve its buffering by already starting to send the HTTP request at the time the first CoAP block is received; any HTTP 408 status code that indicates that the HTTP server became impatient with the resulting transfer can then be mapped into a CoAP 4.08 response code (similarly, 413 maps to 4.13).

For mapping HTTP to CoAP, the intermediary may want to map a single HTTP transfer into a sequence of block-wise transfers. If the HTTP client is too slow delivering a request body on a PUT or POST, the CoAP server might time out and return a 4.08 response code, which in turn maps well to an HTTP 408 status code (again, 4.13 maps to 413). HTTP range requests received on the HTTP side may be served out of a cache and/or mapped to GET requests that request a sequence of blocks that cover the range.

(Note that, while the semantics of CoAP 4.08 and HTTP 408 differ, this difference is largely due to the different way the two protocols are mapped to transport. HTTP has an underlying TCP connection, which supplies connection state, so an HTTP 408 status code can immediately be used to indicate that a timeout occurred during transmitting a request through that active TCP connection. The CoAP 4.08 response code indicates one or more missing blocks, which may be due to timeouts or resource constraints; as there is no connection state, there is no way to deliver such a response immediately; instead, it is delivered on the next block transfer. Still, HTTP 408 is probably the best mapping back to HTTP, as the timeout is the most likely cause for a CoAP 4.08. Note that there is no way to distinguish a timeout from a missing block for a server without creating additional state, the need for which we want to avoid.)

6. IANA Considerations

This document adds the following option numbers to the "CoAP Option Numbers" registry defined by [RFC7252]:

Number	Name	Reference
23	Block2	RFC 7959
27	Block1	RFC 7959
28	Size2	RFC 7959

Table 3: CoAP Option Numbers

This document adds the following response codes to the "CoAP Response Codes" registry defined by [RFC7252]:

Code	Description	Reference
2.31	Continue	RFC 7959
4.08	Request Entity Incomplete	RFC 7959

Table 4: CoAP Response Codes

7. Security Considerations

Providing access to blocks within a resource may lead to surprising vulnerabilities. Where requests are not implemented atomically, an attacker may be able to exploit a race condition or confuse a server by inducing it to use a partially updated resource representation. Partial transfers may also make certain problematic data invisible to Intrusion Detection Systems (IDSs); it is RECOMMENDED that an IDS that analyzes resource representations transferred by CoAP implement the Block options to gain access to entire resource representations. Still, approaches such as transferring even-numbered blocks on one path and odd-numbered blocks on another path, or even transferring blocks multiple times with different content and obtaining a different interpretation of temporal order at the IDS than at the server, may prevent an IDS from seeing the whole picture. These kinds of attacks are well understood from IP fragmentation and TCP segmentation; CoAP does not add fundamentally new considerations.

Where access to a resource is only granted to clients making use of specific security associations, all blocks of that resource MUST be subject to the same security checks; it MUST NOT be possible for unprotected exchanges to influence blocks of an otherwise protected resource. As a related consideration, where object security is employed, PUT/POST should be implemented in the atomic fashion, unless the object security operation is performed on each access and the creation of unusable resources can be tolerated. Future end-to-end security mechanisms that may be added to CoAP itself may have related security considerations, this includes considerations about caching of blocks in clients and in proxies (see Sections 2.10 and 5 for different strategies in performing this caching); these security considerations will need to be described in the specifications of those mechanisms.

A stateless server might be susceptible to an attack where the adversary sends a Block1 (e.g., PUT) block with a high block number: A naive implementation might exhaust its resources by creating a huge resource representation.

Misleading size indications may be used by an attacker to induce buffer overflows in poor implementations, for which the usual considerations apply.

7.1. Mitigating Resource Exhaustion Attacks

Certain block-wise requests may induce the server to create state, e.g., to create a snapshot for the block-wise GET of a fast-changing resource to enable consistent access to the same version of a resource for all blocks, or to create temporary resource

representations that are collected until pressed into service by a final PUT or POST with the more bit unset. All mechanisms that induce a server to create state that cannot simply be cleaned up create opportunities for denial-of-service attacks. Servers SHOULD avoid being subject to resource exhaustion based on state created by untrusted sources. But even if this is done, the mitigation may cause a denial-of-service to a legitimate request when it is drowned out by other state-creating requests. Wherever possible, servers should therefore minimize the opportunities to create state for untrusted sources, e.g., by using stateless approaches.

Performing segmentation at the application layer is almost always better in this respect than at the transport layer or lower (IP fragmentation, adaptation-layer fragmentation), for instance, because there are application-layer semantics that can be used for mitigation or because lower layers provide security associations that can prevent attacks. However, it is less common to apply timeouts and keepalive mechanisms at the application layer than at lower layers. Servers MAY want to clean up accumulated state by timing it out (cf. response code 4.08), and clients SHOULD be prepared to run block-wise transfers in an expedient way to minimize the likelihood of running into such a timeout.

7.2. Mitigating Amplification Attacks

[RFC7252] discusses the susceptibility of CoAP endpoints for use in amplification attacks.

A CoAP server can reduce the amount of amplification it provides to an attacker by offering large resource representations only in relatively small blocks. With this, e.g., for a 1000-byte resource, a 10-byte request might result in an 80-byte response (with a 64-byte block) instead of a 1016-byte response, considerably reducing the amplification provided.

8. References

8.1. Normative References

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8.2. Informative References

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Kepeng Li, Linyi Tian, and Barry Leiba wrote up an early version of the Size option, which is described in this document. Klaus Hartke wrote some of the text describing the interaction of Block2 with Observe. Matthias Kovatsch provided a number of significant simplifications of the protocol.

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Authors' Addresses

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

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

Zach Shelby (editor)
ARM
150 Rose Orchard
San Jose, CA 95134
United States of America

Phone: +1-408-203-9434
Email: zach.shelby@arm.com