A Concise Binary Object Representation (CBOR) of DNS Messages

draft-lenders-dns-cbor
(https://datatracker.ietf.org/doc/draft-lenders-dns-cbor/)

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Carsten Bormann, Thomas C. Schmidt, Matthias Wählisch

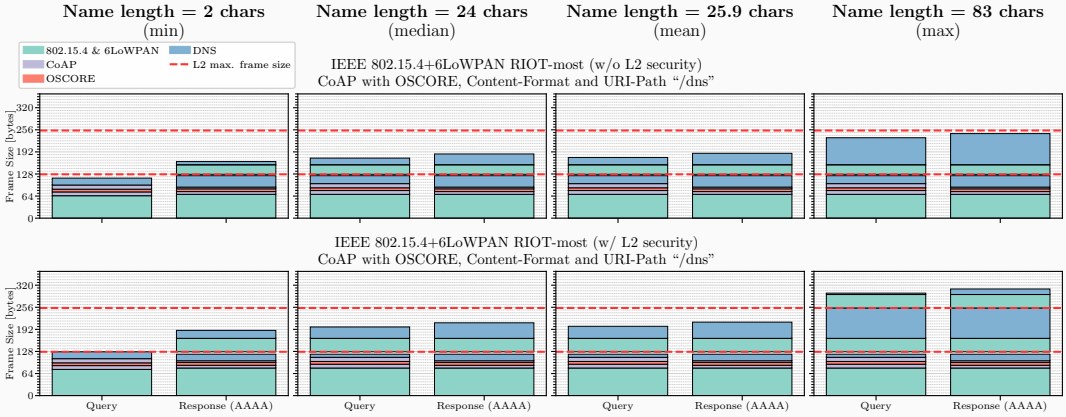
IETF 118, CBOR WG Session, 2023-11-07

Outline

Motivation: DNS in Constrained Networks

Packet size in DoC exceeds 802.15.4 PDU depending on queried name length

⇒ Fragmentation



DNS over CoAP (`draft-ietf-core-dns-over-coap`) messages for different name lengths

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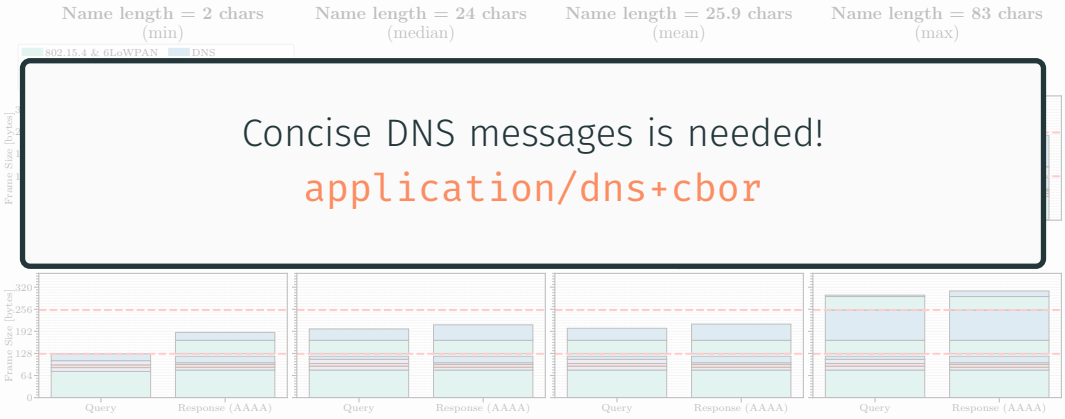


Concise DNS messages is needed!

`application/dns+cbor`

DNS over CoAP (`draft-ietf-core-dns-over-coap`) messages for different name lengths

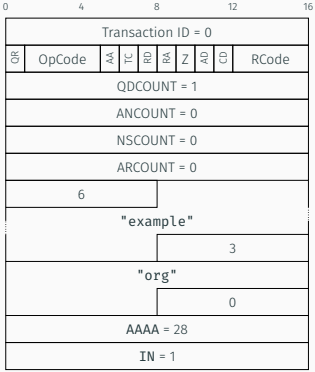
Objectives of draft-lenders-dns-cbor (`application/dns+cbor`)

Provide concise packet format and compressed names and addresses in DNS queries and replies:

1. Using existing implementation: CBOR
2. Encoding of DNS messages in CBOR (conciseness)
3. Omit (redundant) DNS fields in DNS queries and responses (conciseness)
4. Address and name compression using CBOR-packed (compression, optional)

Omitting DNS fields? Some Examples.

Query format (28 bytes)



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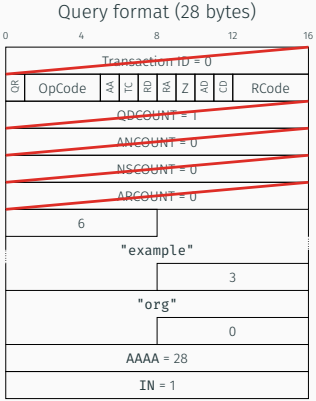

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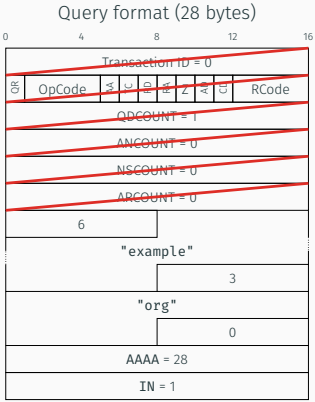

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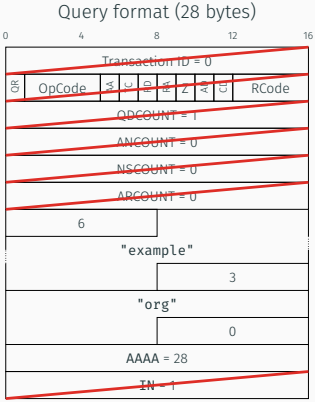
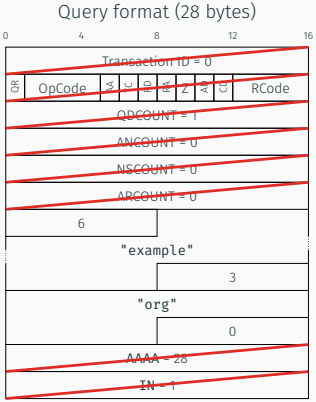


Omitting DNS fields? Some Examples.



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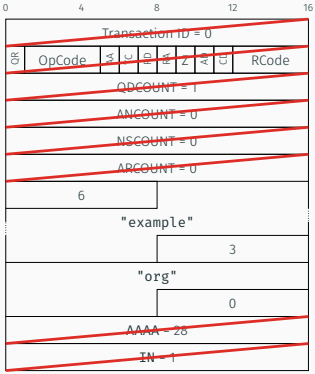
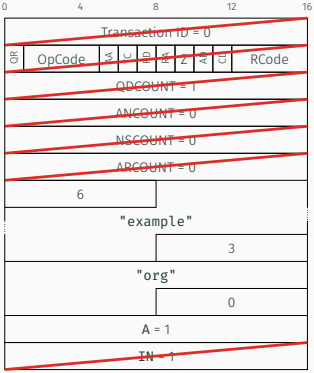



```
81 81 6b 6578616d706c652e6f7267 (14 bytes)
[  [  "example.org"]]
```

Omitting DNS fields? Some Examples.

Query format (28 bytes)




```
81 81 6b 6578616d706c652e6f7267 (14 bytes)
[  [  "example.org"]]
```

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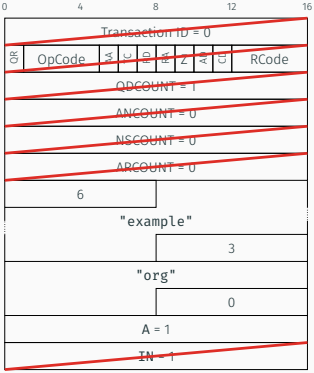
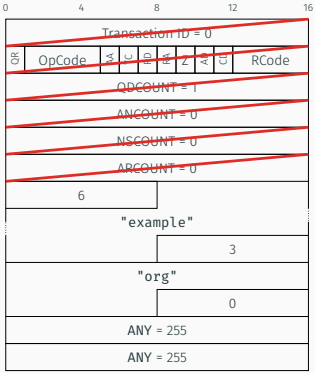



```
81 82 6b 6578616d706c652e6f7267 01 (15 bytes)
[  [  "example.org",            1]]
```

Omitting DNS fields? Some Examples.

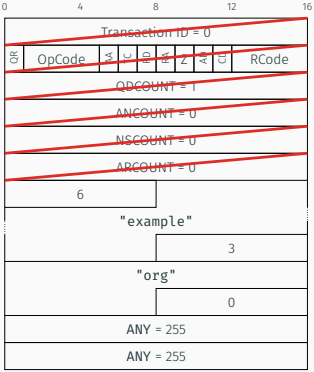
Query format (28 bytes)




```
81 82 6b 6578616d706c652e6f7267 01 (15 bytes)
[  [  "example.org",            1]]
```

Omitting DNS fields? Some Examples.

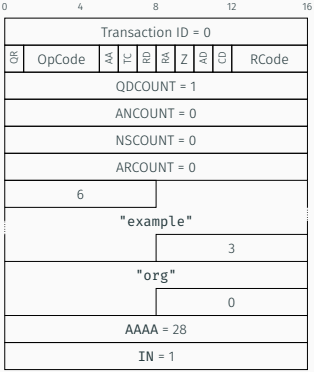
Query format (28 bytes)



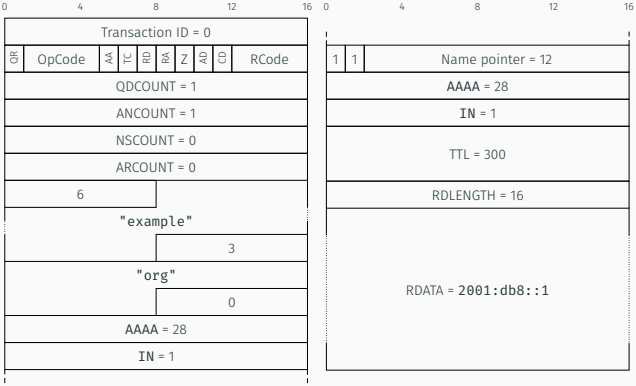

```
81 83 6b 6578616d706c652e6f7267 18 ff 18 ff (18 bytes)
[  [  "example.org",            255,  255]]
```

Omitting DNS fields? Some Examples.

Query format (28 bytes)



Response format (56 bytes)



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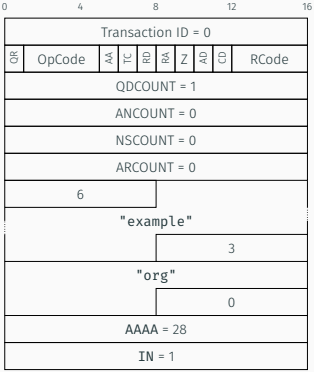

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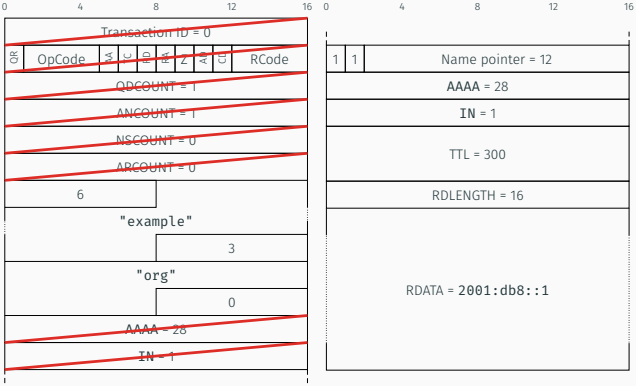

Omitting DNS fields? Some Examples.

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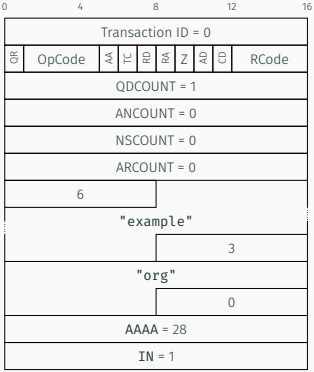

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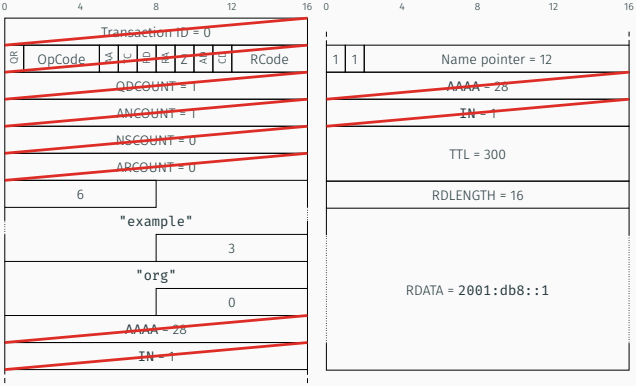

Omitting DNS fields? Some Examples.

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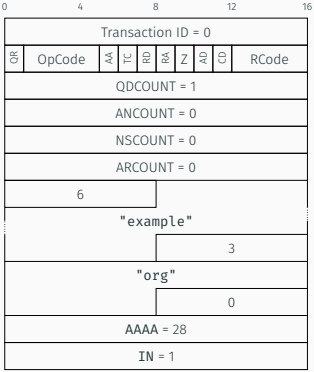

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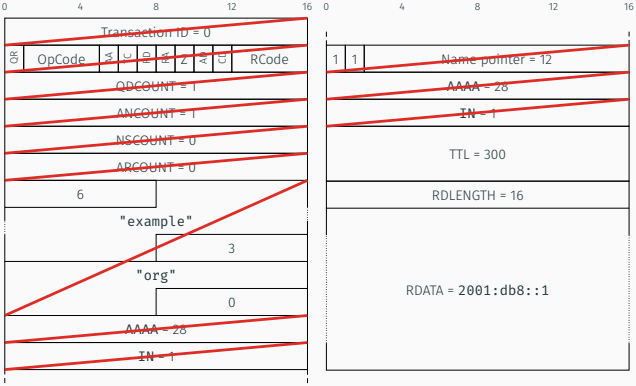
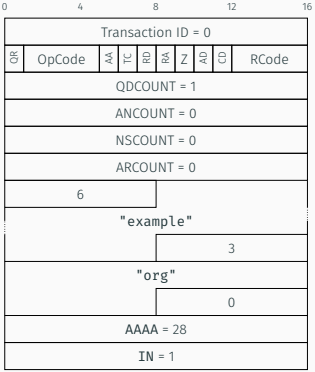
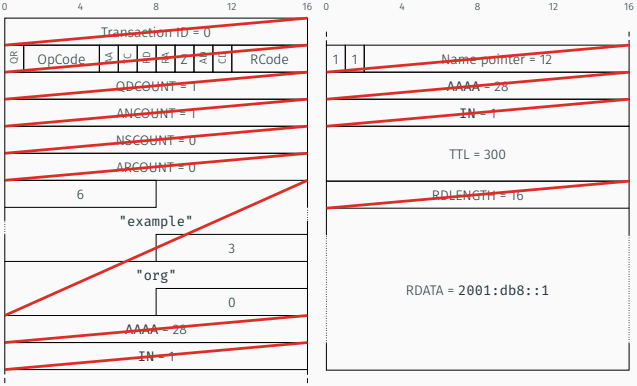


Omitting DNS fields? Some Examples.

Query format (28 bytes)



Response format (56 bytes)



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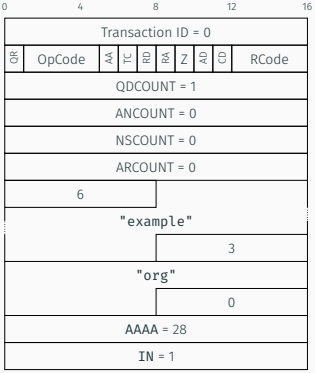

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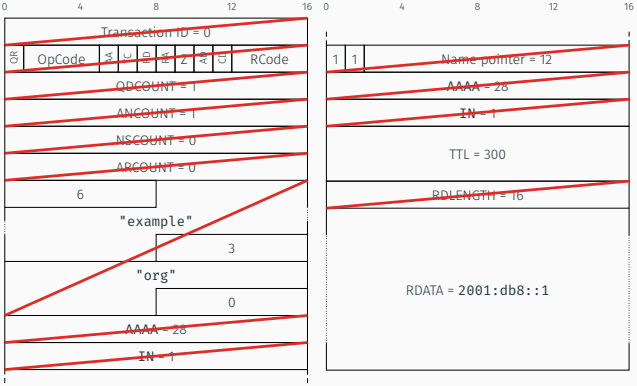
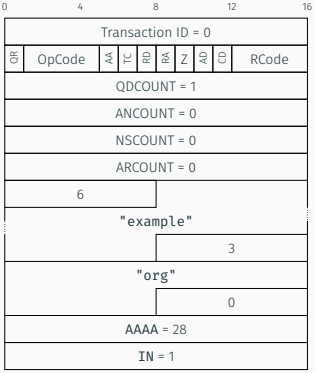



```
81
   81 82 19 012c 50 20010db8000000000000000000000001 (23 bytes)
[
   [  [  300,    h'20010db8000000000000000000000001']]
```

Omitting DNS fields? Some Examples.

Query format (28 bytes)



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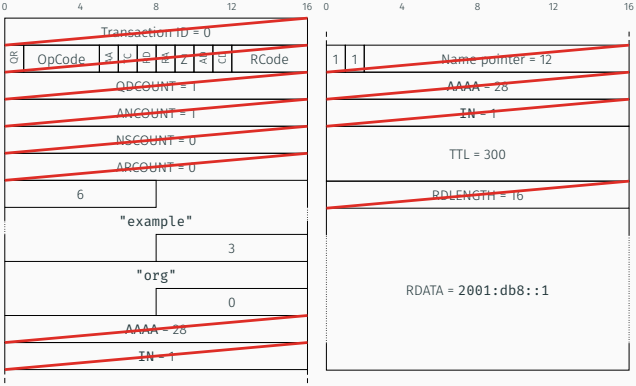


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81
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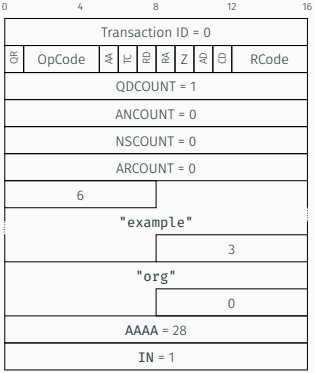


Response format (56 bytes)


```
82
   81 6b 6578616d706c652e6f7267
   81 82 19 012c 50 20010db8000000000000000000000001 (36 bytes)
[
   [  "example.org"],
   [  [  300,    h'20010db8000000000000000000000001']]
```

Changes to DNS+CBOR Draft Since IETF 117 and `-03`

Now at -05

+ Add note on representation of more structured RDATA
+ Provide format description for EDNS OPT Pseudo-RRs
+ Add “Implementation Status” section
- Simplify CDDL to more idiomatic style
- Other clean-up and housekeeping
– Remove DNS transaction IDs
– Remove `int` as representation for `rdata`

EDNS OPT Pseudo-RRs

```
opt-rr = [
  ? udp-payload-size: uint .default 512,
  options: [* opt],
  ? opt-rcode-v-flags,
]
opt = (
  ocode: uint,
  odata: bstr,
)
opt-rcode-v-flags = (
  flags: uint .default 0,
  ? opt-rcode-v,
)
opt-rcode-v = (
  rcode: uint .default 0,
  ? version: uint .default 0,
)
```

Classic DNS format (23 bytes)

```
00 00 29 02 00 00 00 00
00 00 0c 00 0a 00 08 96
0c db 3b 79 af 95 26
```

CBOR (14 bytes)

```
141(                    |d8 8d
 [                      | 81
  [                     |  82
   10,                  |   0a
                        |   48
   h'960cdb3b79af9526'  |    96 0c db 3b
  ]]                    |    79 af 95 26
)                       |
```

Evaluation: Data Corpus

YourThings[1] IoTFinder[2] MonIoTr[3]

- Collected throughout 2019
- 90 consumer IoT devices from 50 vendors
  + Phones, Tablets, PCs, ... (in IoTFinder & YourThings)
- 1.20 million queries
- 2.74 million responses
  - 2.07 million w/o mapped query (IoTFinder contains only responses)
  - 0.66 million w/ mapped query

---

[1] O. Alrawi, C. Lever, M. Antonakakis, and F. Monrose. 2019. **SoK: Security Evaluation of Home-Based IoT Deployments**. In *IEEE S&P 2019*. 1362–1380.

[2] R. Perdisci, T. Papastergiou, O. Alrawi, and M. Antonakakis. 2020. **IoTFinder: Efficient Large-Scale Identification of IoT Devices via Passive DNS Traffic Analysis**. In *IEEE EuroS&P 2020*. 474–489.

[3] J. Ren, D.J. Dubois, D. Choffnes, A.M. Mandalari, R. Kolcun, and H. Haddadi. 2019. **Information Exposure for Consumer IoT Devices: A Multidimensional, Network-Informed Measurement Approach**. In *Proc. of the Internet Measurement Conference (IMC)*. ACM.

Evaluation: Method

- Implementation: `https://github.com/netd-tud/cbor4dns`
- Applied CBOR+DNS to data corpus
  - Elide question section in response if query is present in data corpus
  - For all: unpacked and packed

    unpacked "classic" CBOR+DNS (`application/cbor+dns`)

    packed CBOR-packed+DNS (`application/cbor+dns;packed=1`)

Compression Ratios & Byte Savings

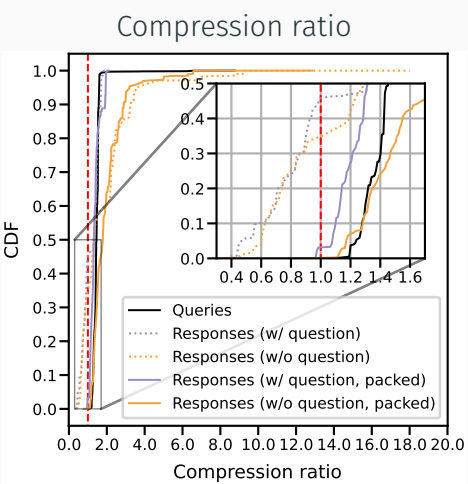
Compression ratio

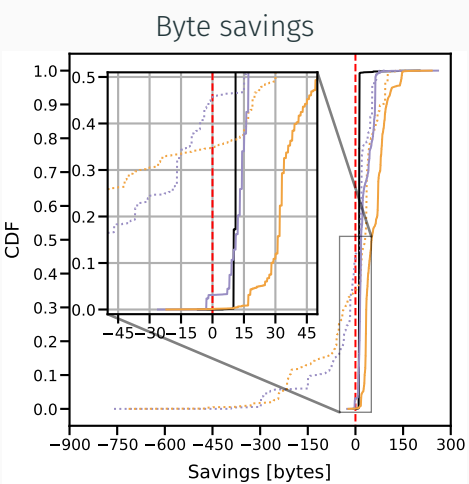
$$\frac{\text{len(classic format)}}{\text{len(CBOR format)}}$$

Byte savings

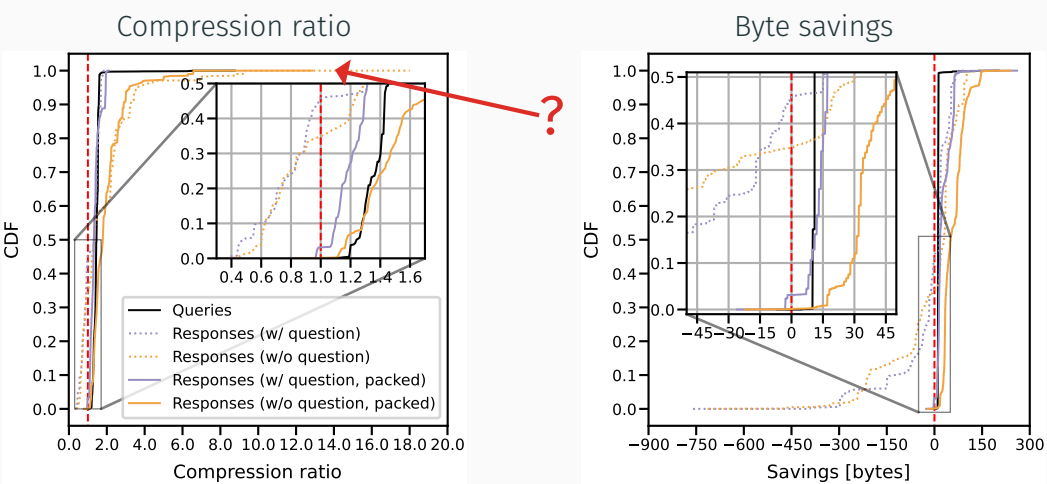
$$\text{len(classic format)} - \text{len(CBOR format)}$$

Compression Ratios & Byte Savings

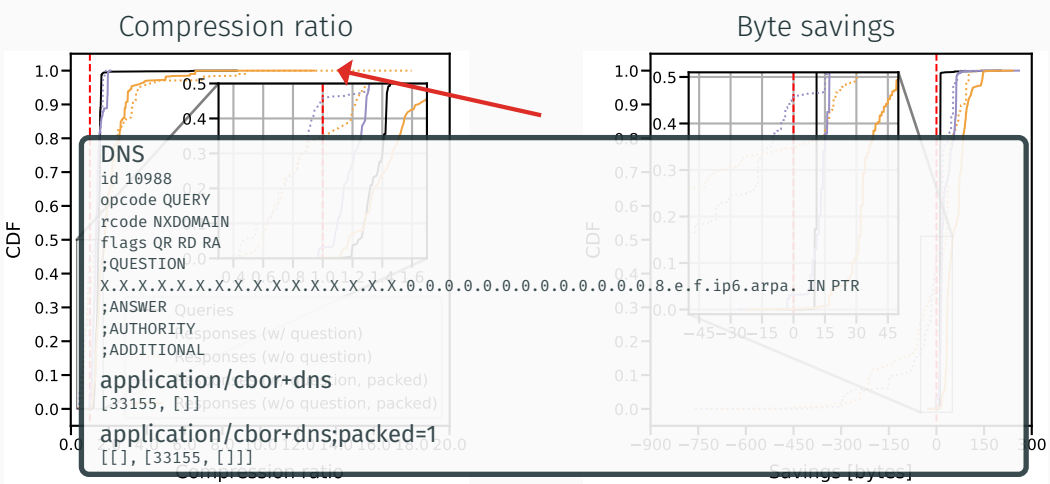




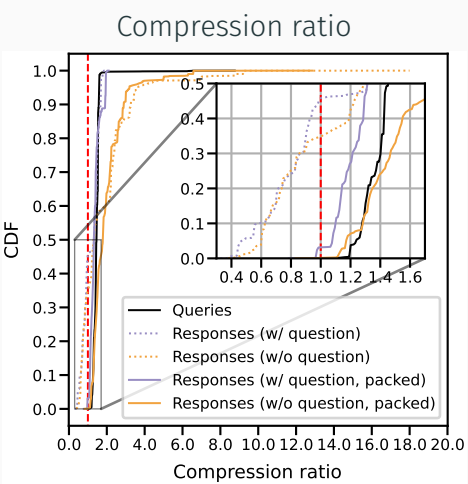
Compression Ratios & Byte Savings

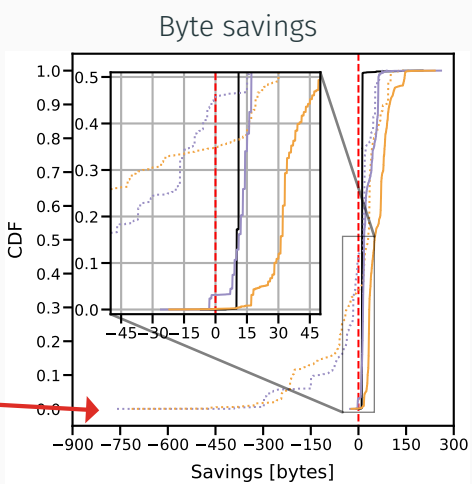


Compression Ratios & Byte Savings



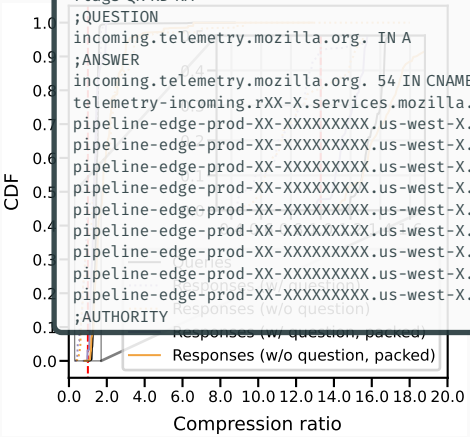
Compression Ratios & Byte Savings

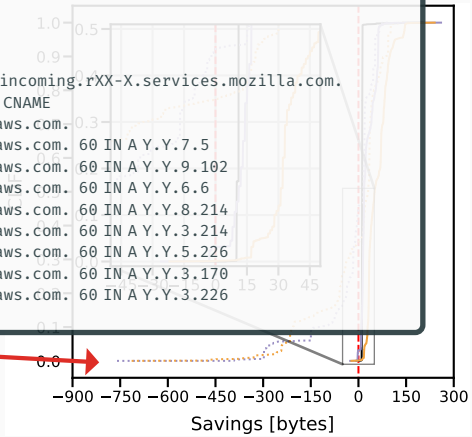




Compression Ratios & Byte Savings

```
DNS
id 63962
opcode QUERY
rcode NOERROR
flags QR RD RA
;QUESTION
incoming.telemetry.mozilla.org. IN A
;ANSWER
incoming.telemetry.mozilla.org. 54 IN CNAME telemetry-incoming.rXX-X.services.mozilla.com.
telemetry-incoming.rXX-X.services.mozilla.com. 299 IN CNAME
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com.
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.7.5
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.9.102
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.6.6
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.8.214
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.3.214
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.5.226
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.3.170
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.3.226
;AUTHORITY
```

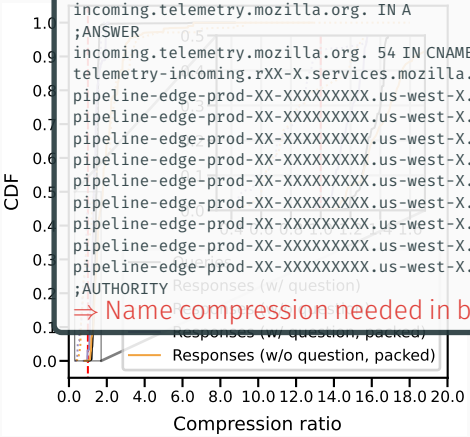


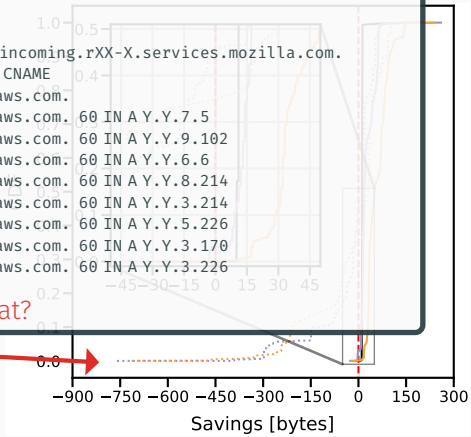


Compression Ratios & Byte Savings

```
DNS
id 63962
opcode QUERY
rcode NOERROR
flags QR RD RA
;QUESTION
incoming.telemetry.mozilla.org. IN A
;ANSWER
incoming.telemetry.mozilla.org. 54 IN CNAME telemetry-incoming.rXX-X.services.mozilla.com.
telemetry-incoming.rXX-X.services.mozilla.com. 299 IN CNAME
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com.
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.7.5
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.9.102
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.6.6
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.8.214
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.3.214
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.5.226
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.3.170
pipeline-edge-prod-XX-XXXXXXXXX.us-west-X.elb.amazonaws.com. 60 IN A Y.Y.3.226
;AUTHORITY
```

⇒ Name compression needed in base format?





Possible Choices for Names in Constrained Networks

Keep Uncompressed

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Keep Uncompressed

Bespoke DNS solution

Possible Choices for Names in Constrained Networks

Keep Uncompressed

Bespoke DNS solution

Use existing solution (CBOR-packed)

Ideas for Name Compression

Discussed @ 2023-10-04 CBOR Interim:

1. Classic DNS format style: Reference name components within CBOR object
2. CBOR-packed “lite”: Reference name suffixes in pre-defined table

Example Response for Idea Explanations

A PTR (record type 12) request for “example.org”:

```
[ ["example.org", 12, 1],
  [[3600, "_coap._udp.local"]],
  [[3600, 2, "ns1.example.org"], [3600, 2, "ns2.example.org"]],
  [ [ "_coap._udp.local", 3600, h'20010db8000000000000000000000001'],
    [ "ns1.example.org", 3600, h'20010db8000000000000000000000002'],
    [ "ns2.example.org", 3600, h'20010db8000000000000000000003535'] ] ]
```

Idea 1: Reference Name Components

- Loosely based on Christian's idea[1]:
  - Current draft: `domain-name = tstr .regexp "([^.]+[.])*[^.]+"`
  - Proposal: `domain-name = (*comp)`
    (*cf.* `core-href`)
- Use componified name to allow for `tag(uint)` in name, *i.e.*, reference:

  `comp = tstr / #6.`*t*`(uint)`

  To be decided: 1+0 bytes tag (≈2 bytes for reference like DNS) or larger tag

[1] `https://mailarchive.ietf.org/arch/msg/cbor/JOHCCBOzC46PrSq-61MMev--mpU/`

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Semantics of *t*(*i*) for name construction:

- Start at name components from *i*-th `tstr` in CBOR object
- Stop if object is neither `tstr` nor tag *t* (i.e. not `comp`)
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```
[ ["example", "org", 12, 1],
  [[3600, "_coap", "_udp", "local"]],
  [[3600, 2, "ns1", t(0)], [3600, 2, "ns2", t(0)]],
  [ [ t(2), 3600,
      h'20010db8000000000000000000000001'],
    [ t(5), 3600,
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  - Current
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    (*cf.*
- Use com

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Implicit table

```
/0/ [["example", "org"],
/1/  ["org"],
/2/  ["_coap", "_udp", "local"],
/3/  ["_udp", "local"],
/4/  ["local"],
/5/  ["ns1", t(0)],
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Could be seen as a variant of CBOR-packed with

- Implicit table building
- Alternative referencing syntax and semantics

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Idea 2: CBOR-packed “Lite”

- More lightweight version of proposal by Lemogue et al.
  - Use array instead of dict for `name_ref`
  - Basically `application/cbor+dns;packed=1`
    but only take names into account for table building

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```
[ ["example.org", "_coap._udp.local", 216("ns1."), 216("ns2.")]
  [⓪, 12, 1],
  [3600, ①]],
  [[3600, 2, ②], [3600, 2, ③]],
  [ [①, 3600, h'20010db8000000000000000000000001'],
    [②, 3600, h'20010db8000000000000000000000002'],
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(Reminder: Simple value ⓘ = Use table entry *i* as value; `216(tstr)` = Use table entry 0 as suffix for `tstr`)

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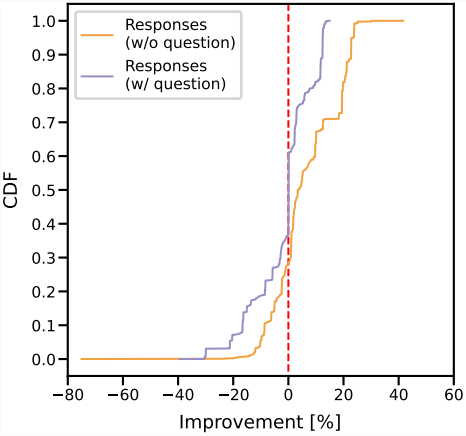
Evaluation: Improvement of Packed Lite Over Component Referencing



$$\frac{\text{len(comp. ref.) - len(packed lite)}}{\text{len(comp. ref.)}}$$

Using 1+0 tag for component referencing (comp. ref.)

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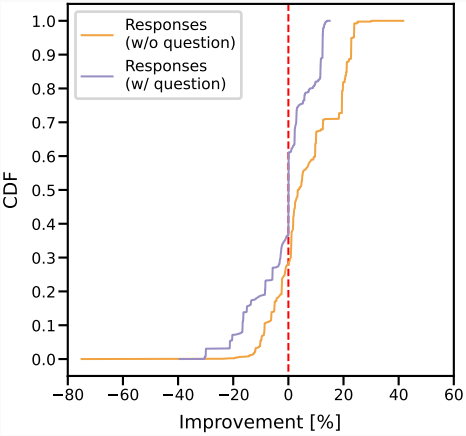

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Using 1+0 tag for component referencing (comp. ref.)

- For $\approx 70\%$ of responses w/o question: $> 0\%$ improvement
- For improvement $< 0\%$: Mostly overhead from extra list

Conclusion

Name compression leads compression ratio >100% for nearly all responses

Benefits of *component referencing*

- *Conciseness*
- *Simplicity*
- *Familiarity*

Benefits of *packed lite*

- *Consistency*
- *Efficiency*

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- *Efficiency*

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Benefits of *packed lite*

- *Consistency* No new reference syntax, no new table building, just CBOR-packed
- *Efficiency* More responses made smaller compared to component referencing

Which way should we go?

Any other ideas?
Implicit tables for CBOR-packed in general?