C-DNS:

A DNS Packet Capture Format

ICANN DNS Engineering Team

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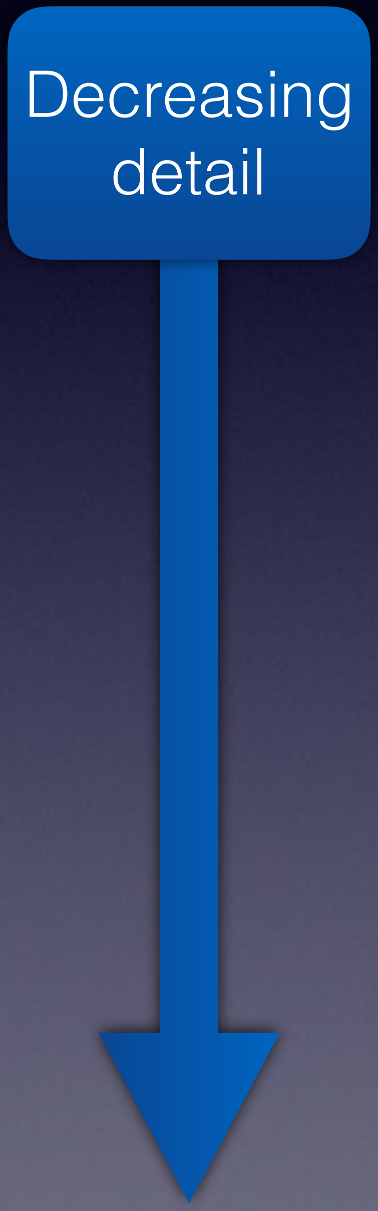
C-DNS Agenda

- Motivation for a new format
- Design decisions
- Describe Compacted-DNS (C-DNS) format
- Standardisation effort: draft-ietf-dnsop-dns-capture-format
- Implementation status

DNS Packet Capture

- Capturing DNS traffic on the wire: Why do it?
  - General traffic analysis
  - Security - detect attacks in real time
  - Post event analysis - research
    - Community efforts e.g. DITL

What is done today?



- PCAP files - full packet capture
- DNS message capture tools
    - DNSTAP, DNSCAP, PacketQ
- DSC - counts of DNS of traffic metrics

What is done today?

- BUT no ***standard*** interchange format for DNS traffic
- PCAP is very common
  - However contains lots of information not directly relevant to DNS analysis

Larger than necessary capture files

Data Capture Environments

Wide range of possibilities…..

Hosting	Conditions	Hardware	Network
Self-hosted	Well provisioned, steady state	Port mirroring	Out-of-band upload
Third-party hosted	Heavily loaded	Network tap	Limited out-of-band upload
Third-party hardware	Under attack	Same h/w as nameserver	Everything in-band

Increasingly constrained

C-DNS Project Background

- ICANN DNS Engineering team is responsible for the Root Server operated by ICANN
- DNS-STATS org created in 2014: A covering entity for the implementation of open source DNS statistics collection and presentation software.
- Sinodun contracts for DNS Eng Team on DNS-STATS work e.g. *Hedgehog* - a DNS traffic statistics presentation tool (DSC XML)

C-DNS Project Background

- ICANN operates 155+ anycast instances, 7 billion q/day

Majority are hosted, in many different types of networks, by many different organisations.
Some constrained, AND all on a 1RU server

- Historically used a combination DSC XML + PCAP
- Now need a more general purpose and scalable solution

C-DNS Project Goal:
Target most limited use case

- Data collection on same hardware as nameserver
- Constrained instance resources: CPU, bandwidth
  (Focus on serving DNS, not capturing DNS!)
- Collected data stored on same hardware
  (At least temporarily)
- Upload will use the same interface as DNS traffic
  (Can be artificially throttled)

Technical requirements

1. **Minimise the file size** for storage and transmission

2. **Minimise the overhead** of producing the packet capture files
   - And further general purpose compression

3. Desirable: **Re-construction** e.g. PCAP

Design Considerations (1)

1. **Basic Unit is Q/R item:** Combine DNS Query and associated Response
    - A single DNS ‘transaction’, commonality in data
2. **Collect ‘default’ Q/R data:** Optionally capture other data
    - Storage constraints vs ability to reconstruct fully
3. **Block storage**: Collected data into blocks of Q/R items
    - Abstract common data and reference by indexing e.g. IP addresses, QNAMES

Use DNS specific domain knowledge to achieve compression

Design Considerations (2)

4. **Also collect metadata**: ICMP, TCP resets, malformed DNS counts

5. **Optionally collect malformed DNS packets**: Any structured format is limited in what can be recorded

    - Malformed queries generate well formed responses
    - Attack traffic may be malformed

What storage format to use?

- Considered several binary representations: CBOR, Apache Avro, Protobuffers
- Assume further compression with a general purpose tool (xz, gzip,…)

Testing showed only **minor** size differences between the formats
=> So consider other factors

CBOR

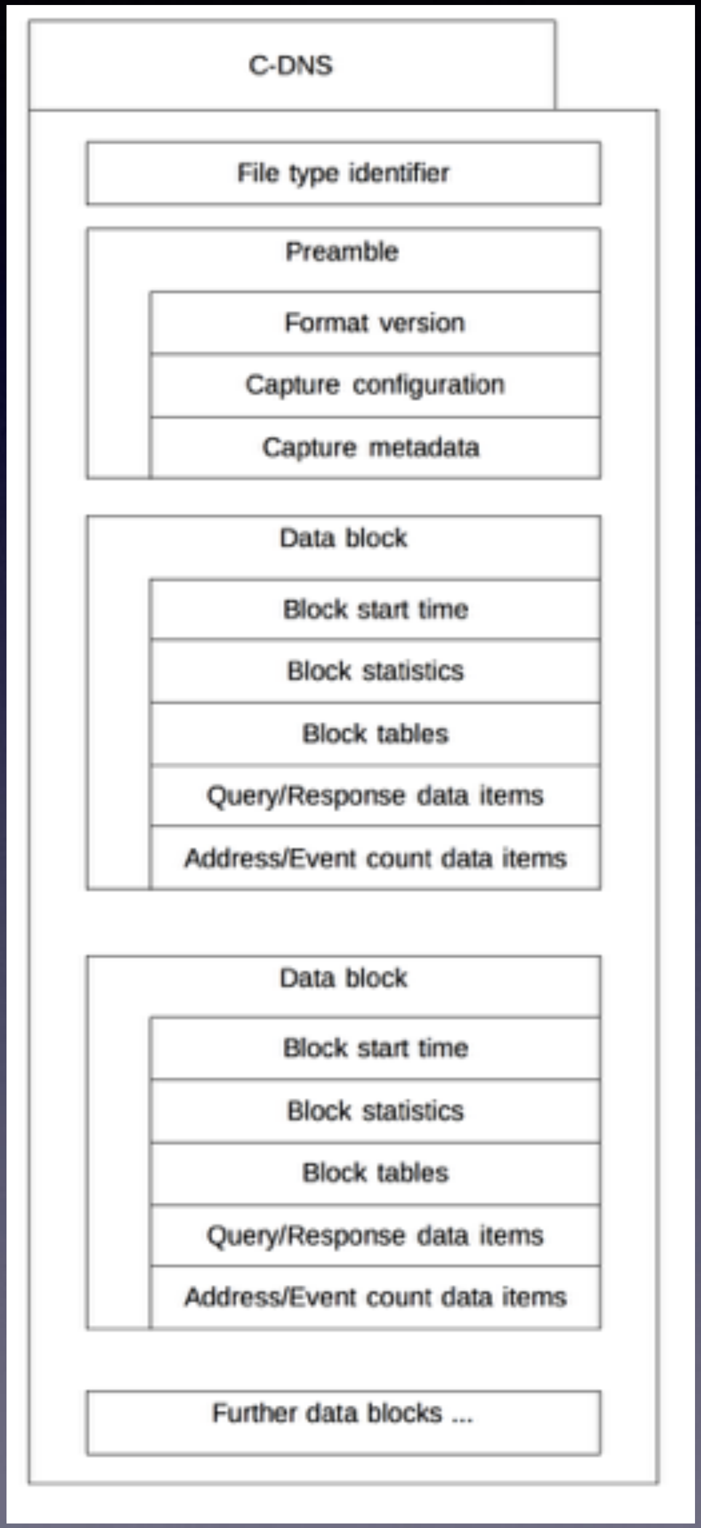
- What is it?

A serialisation format comparable to JSON but with binary representation

- Why use it?
  - IETF standard (RFC7049)
  - Simple format, simple to implement (16 languages)
  - CDDL draft - CBOR data definition language
  - Converts to JSON nicely

C-DNS Format

C-DNS Conceptual Overview



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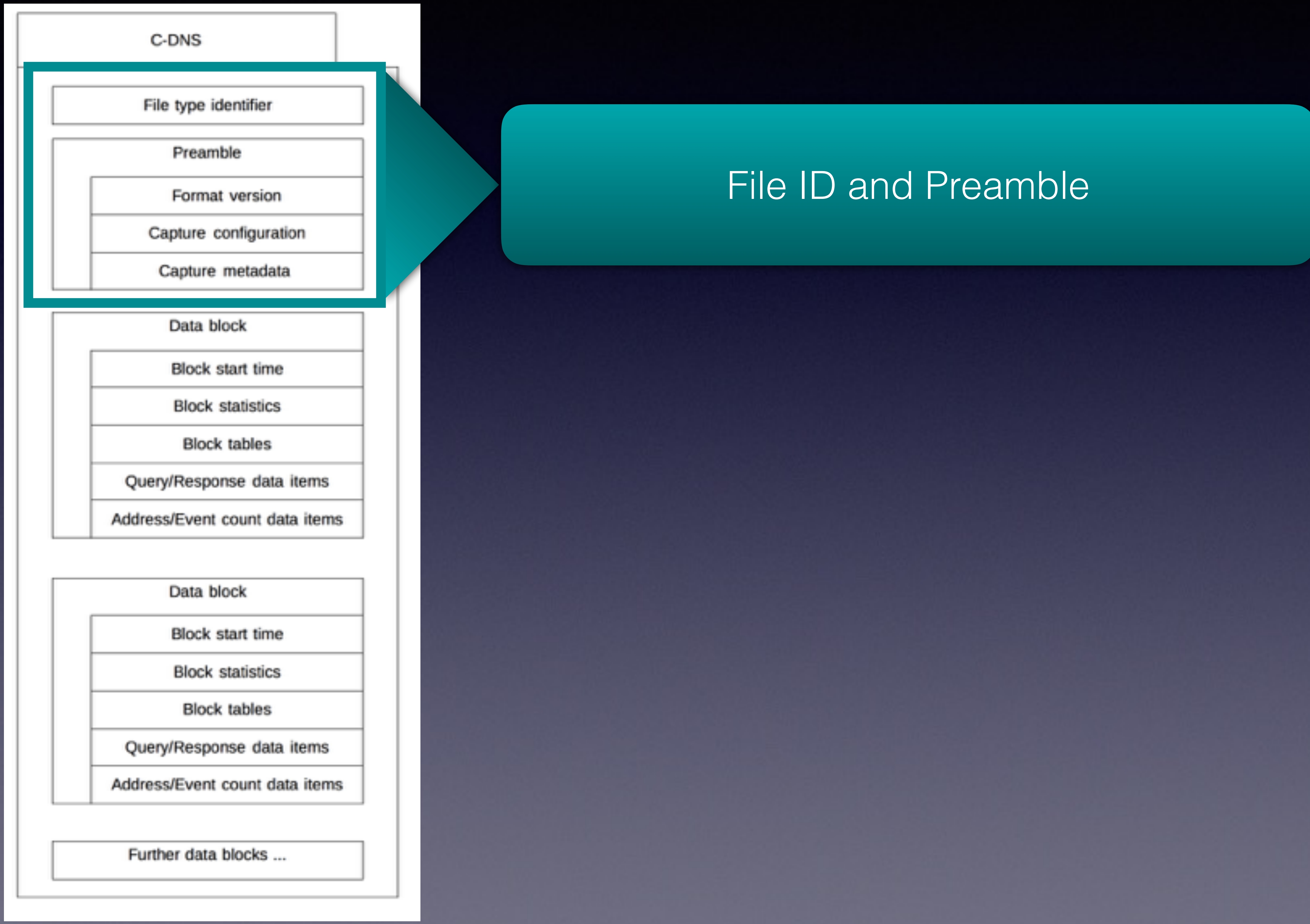

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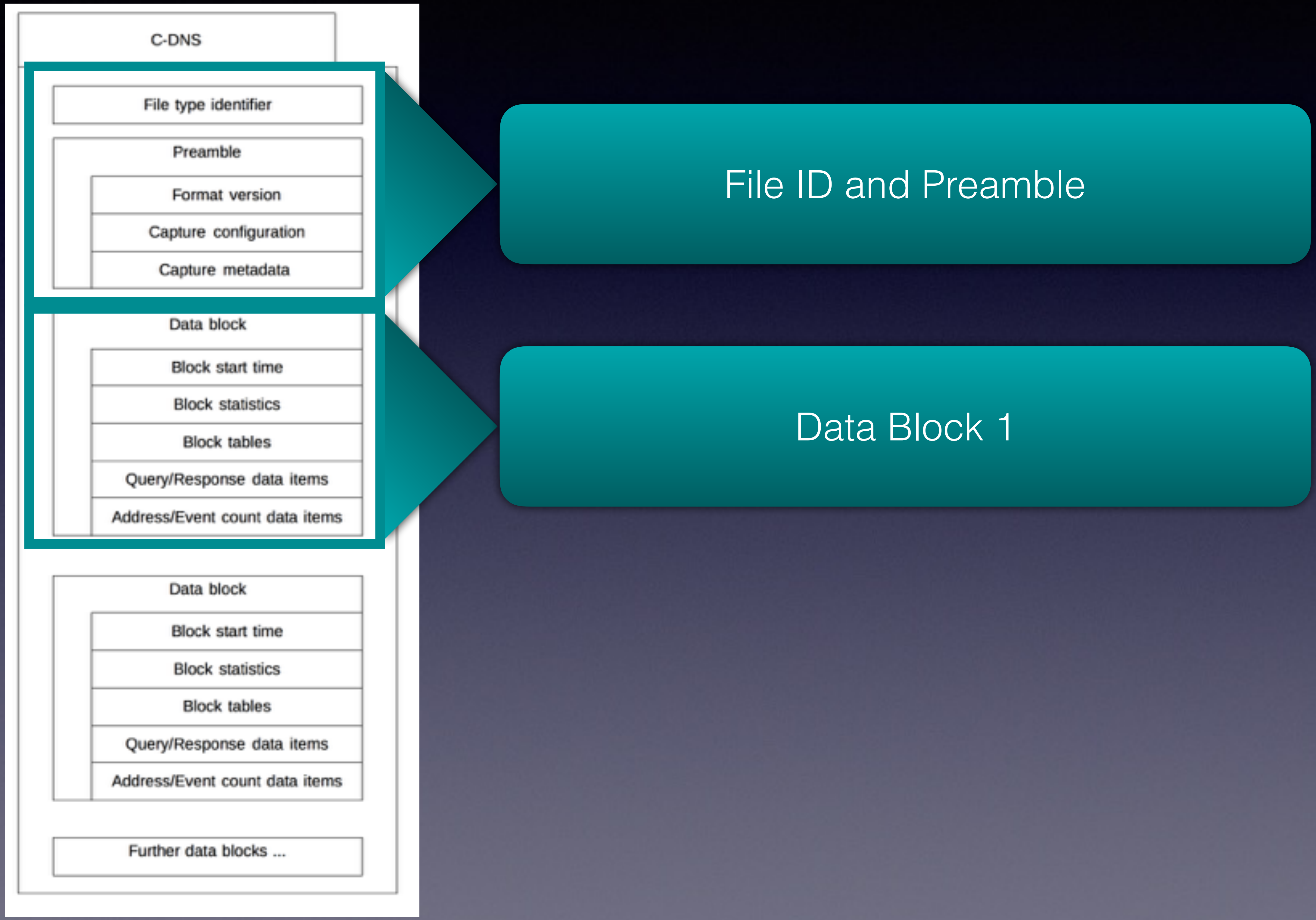

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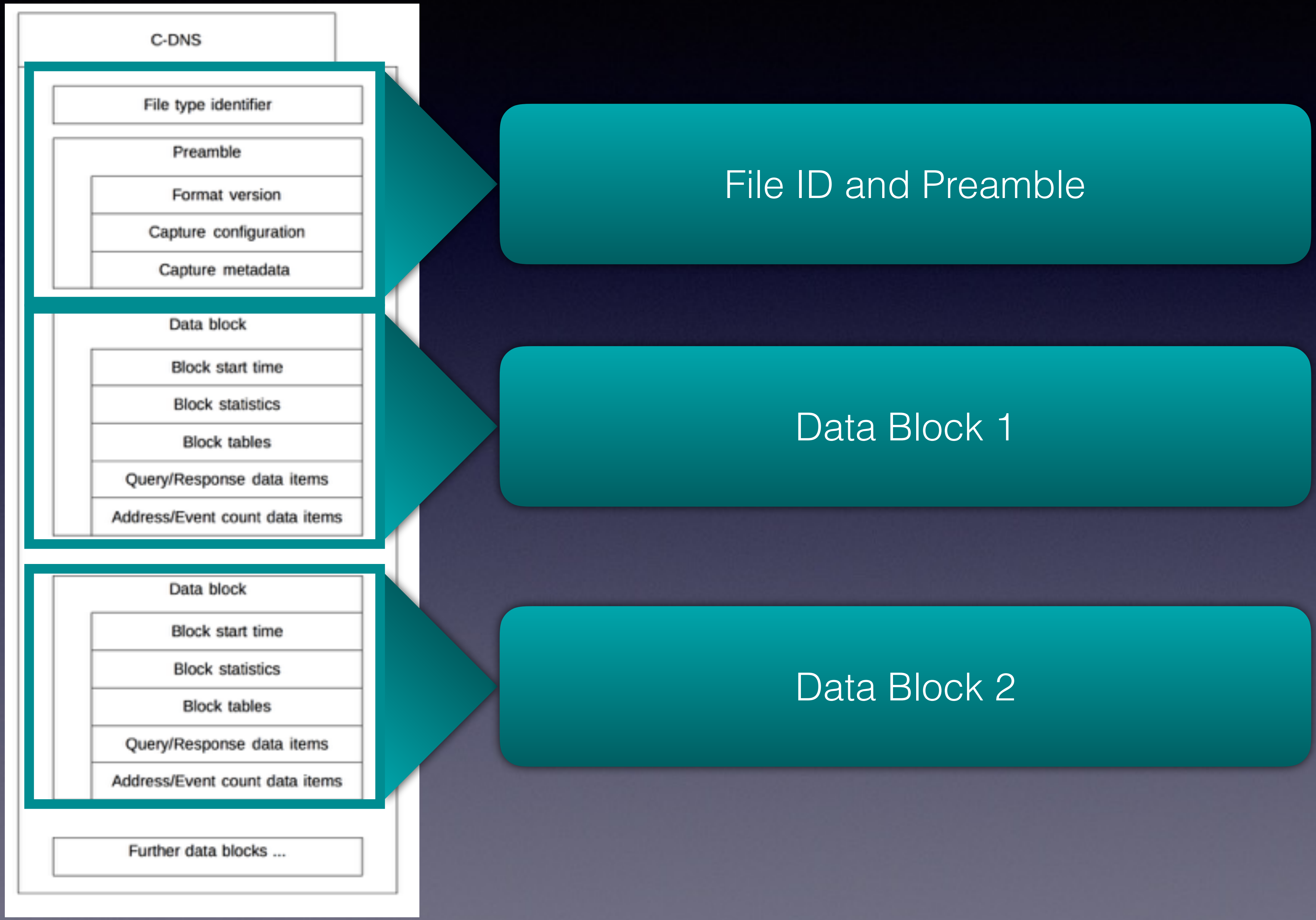

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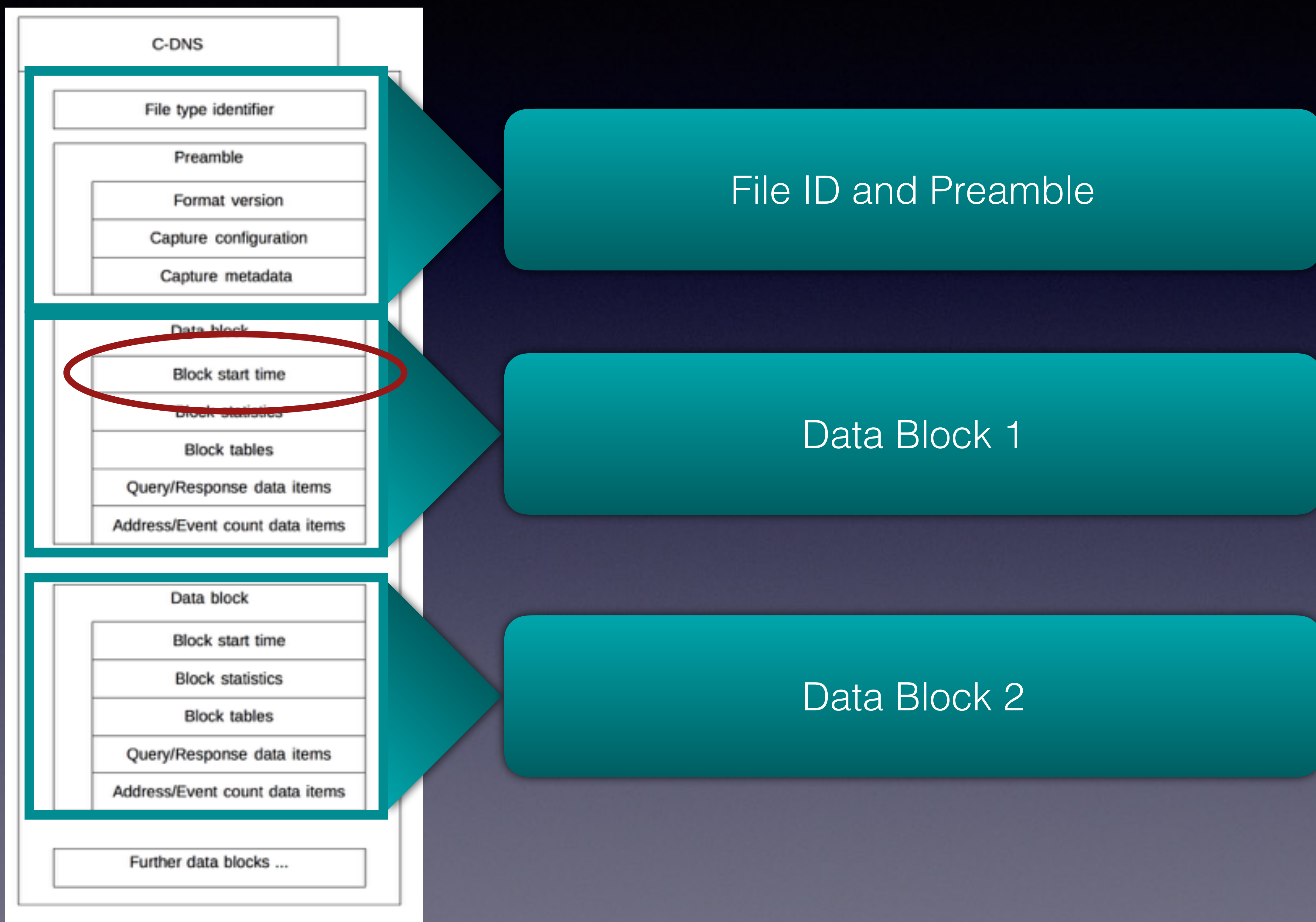

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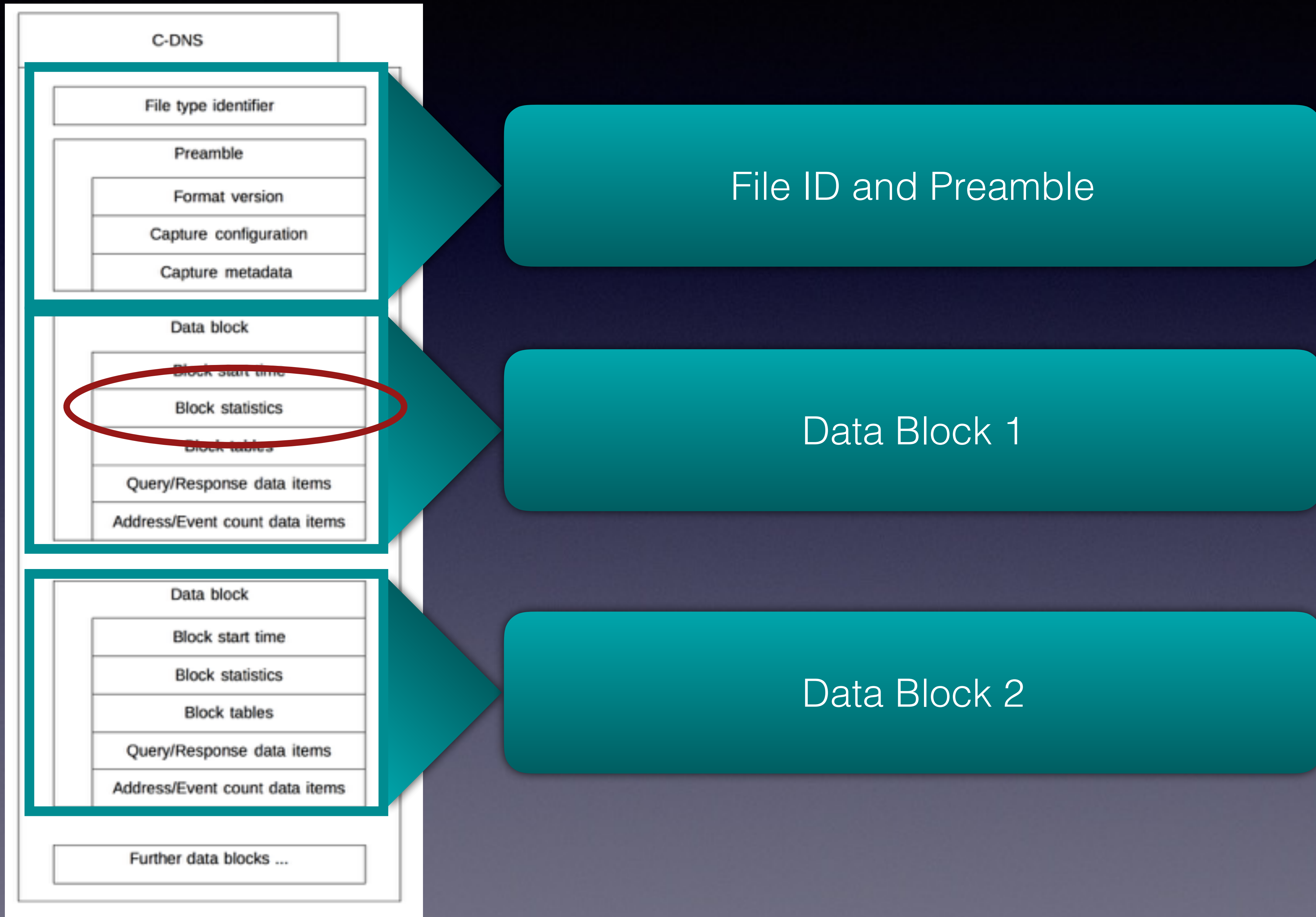

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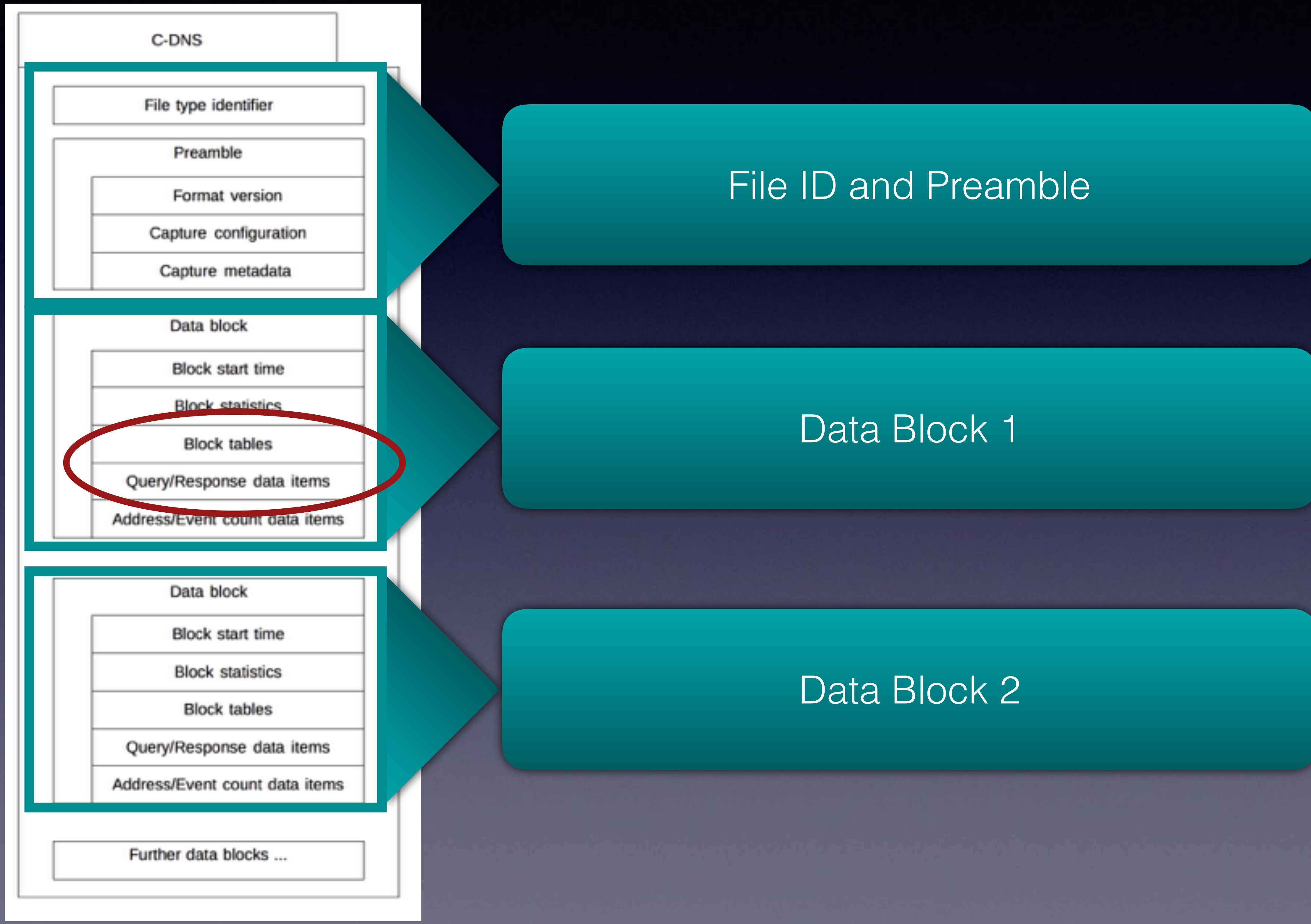

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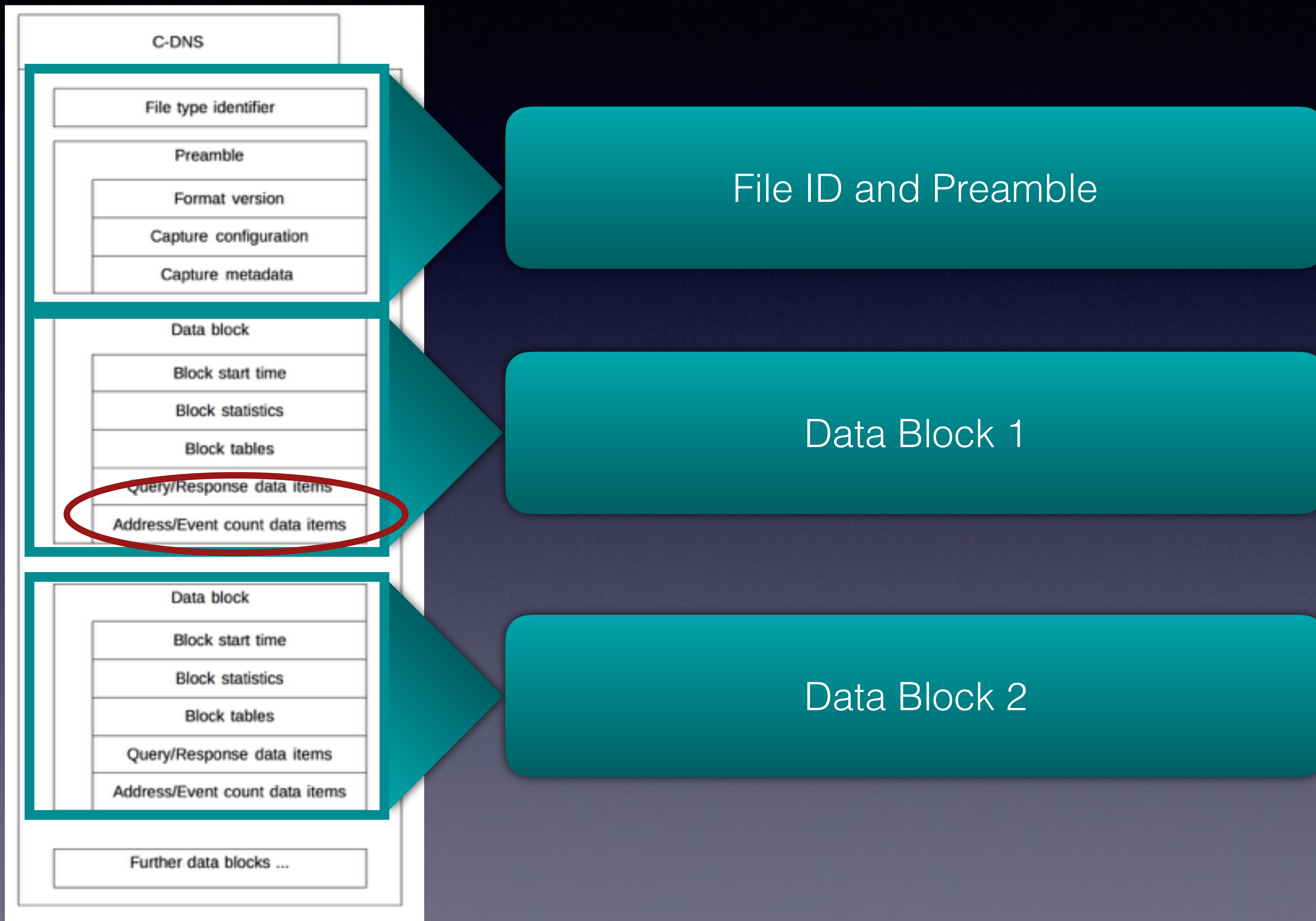

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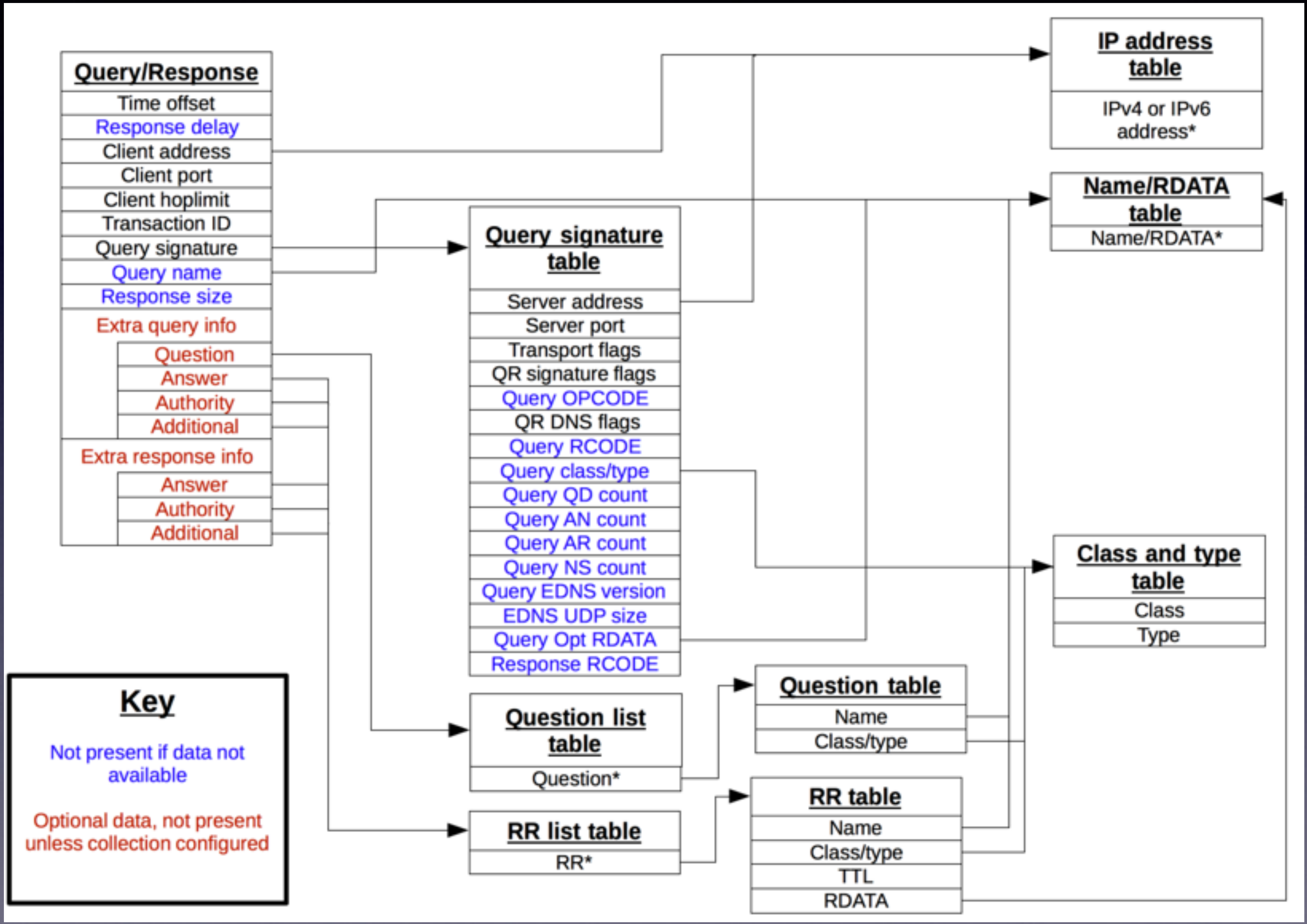

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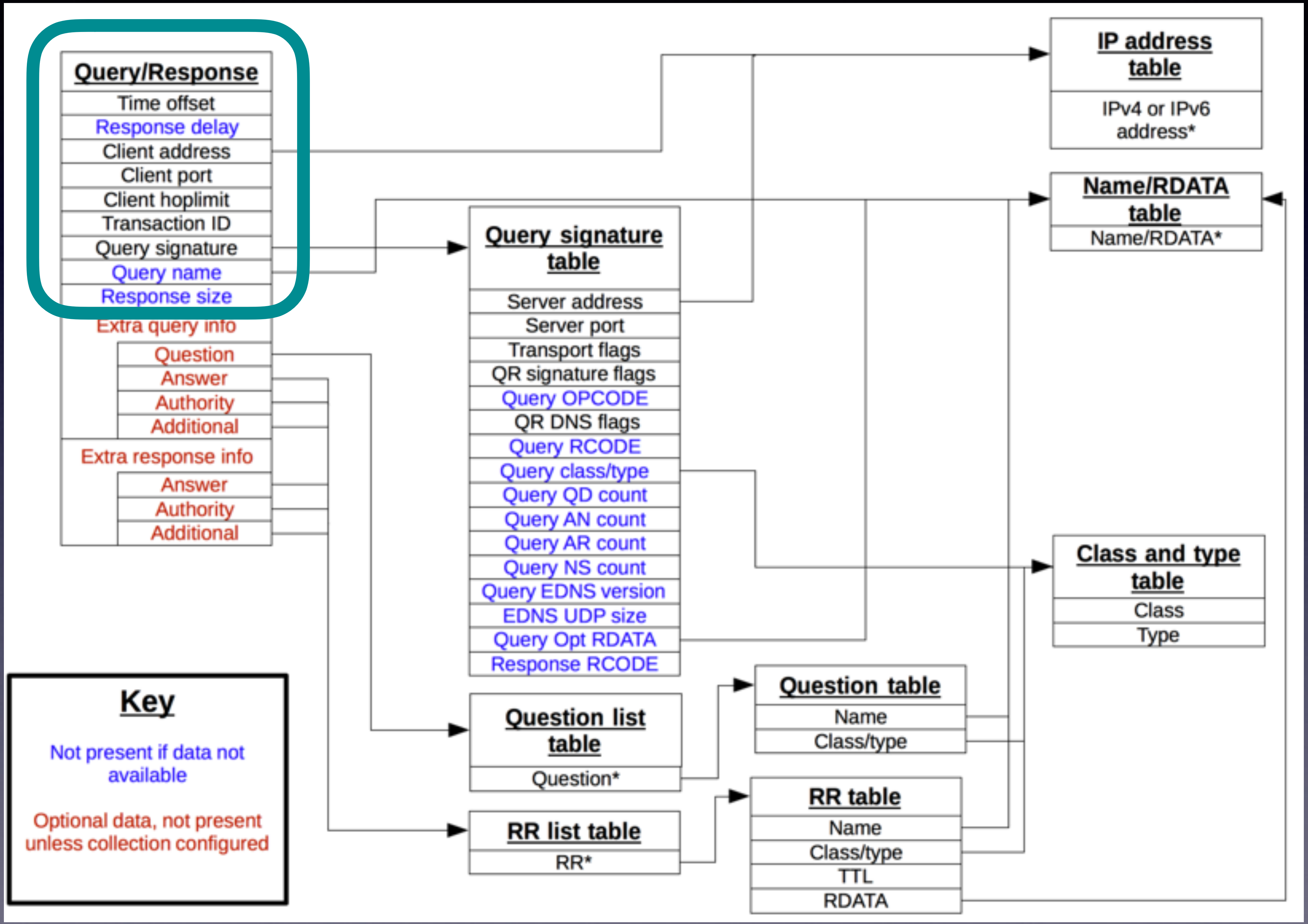

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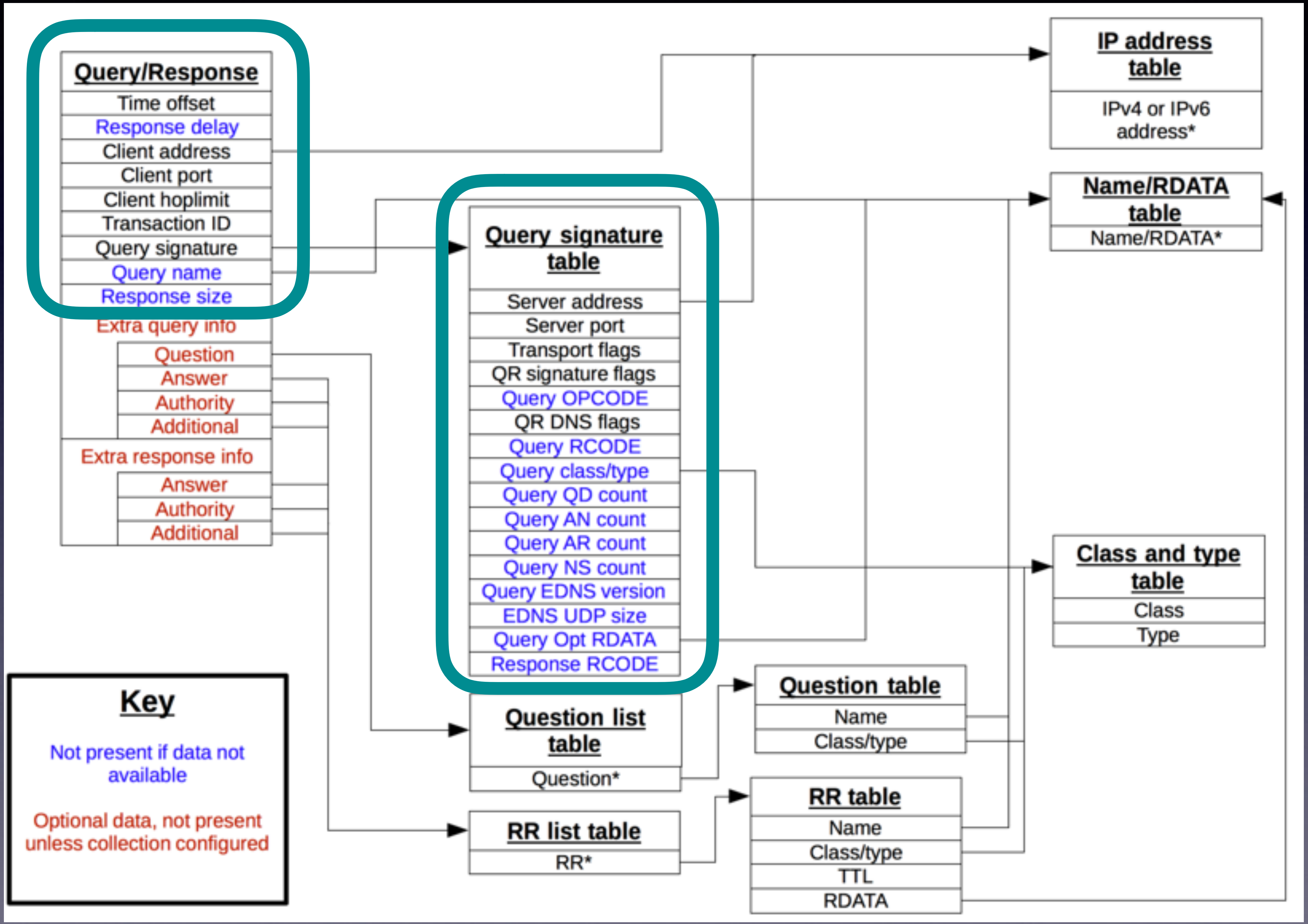

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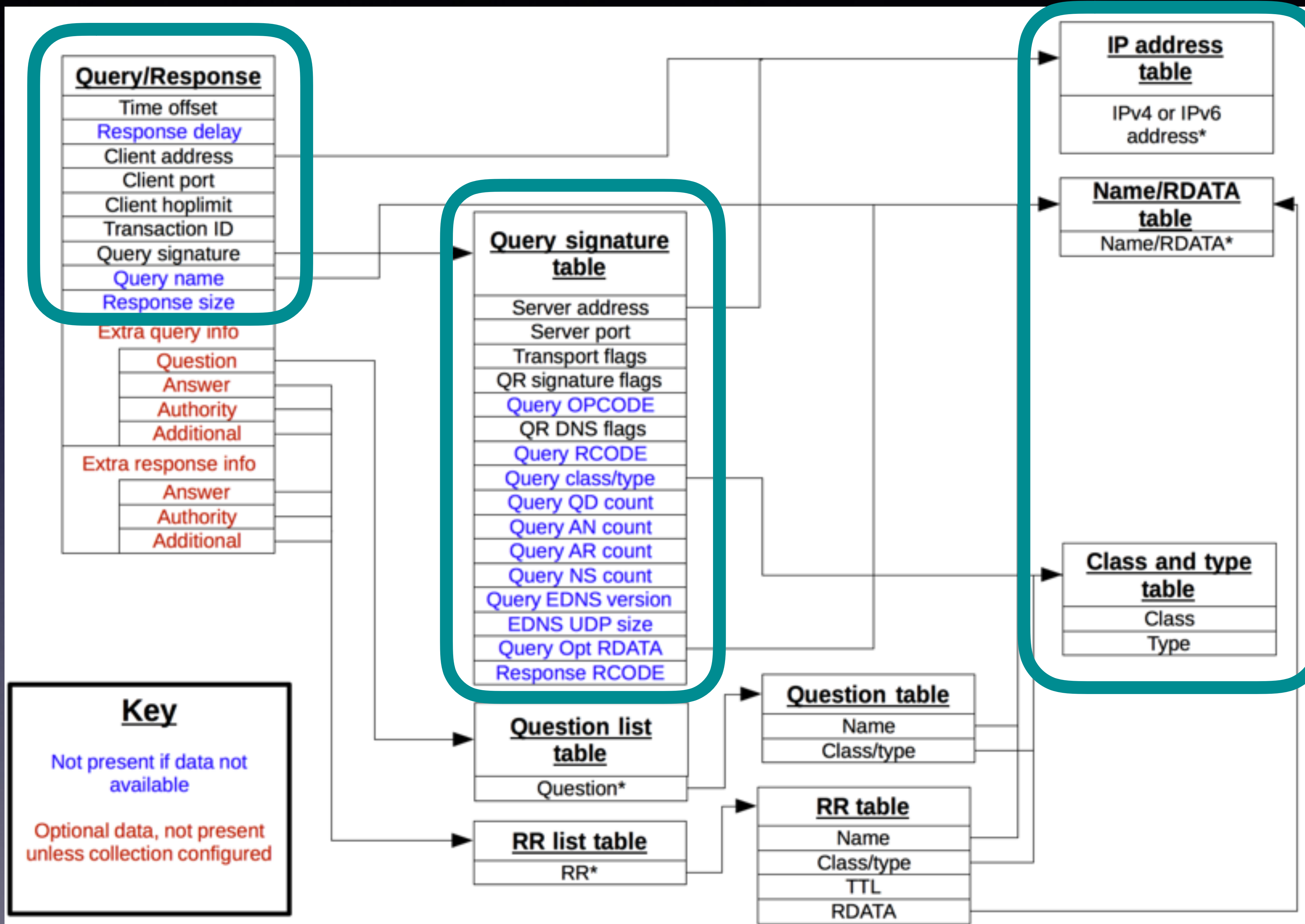

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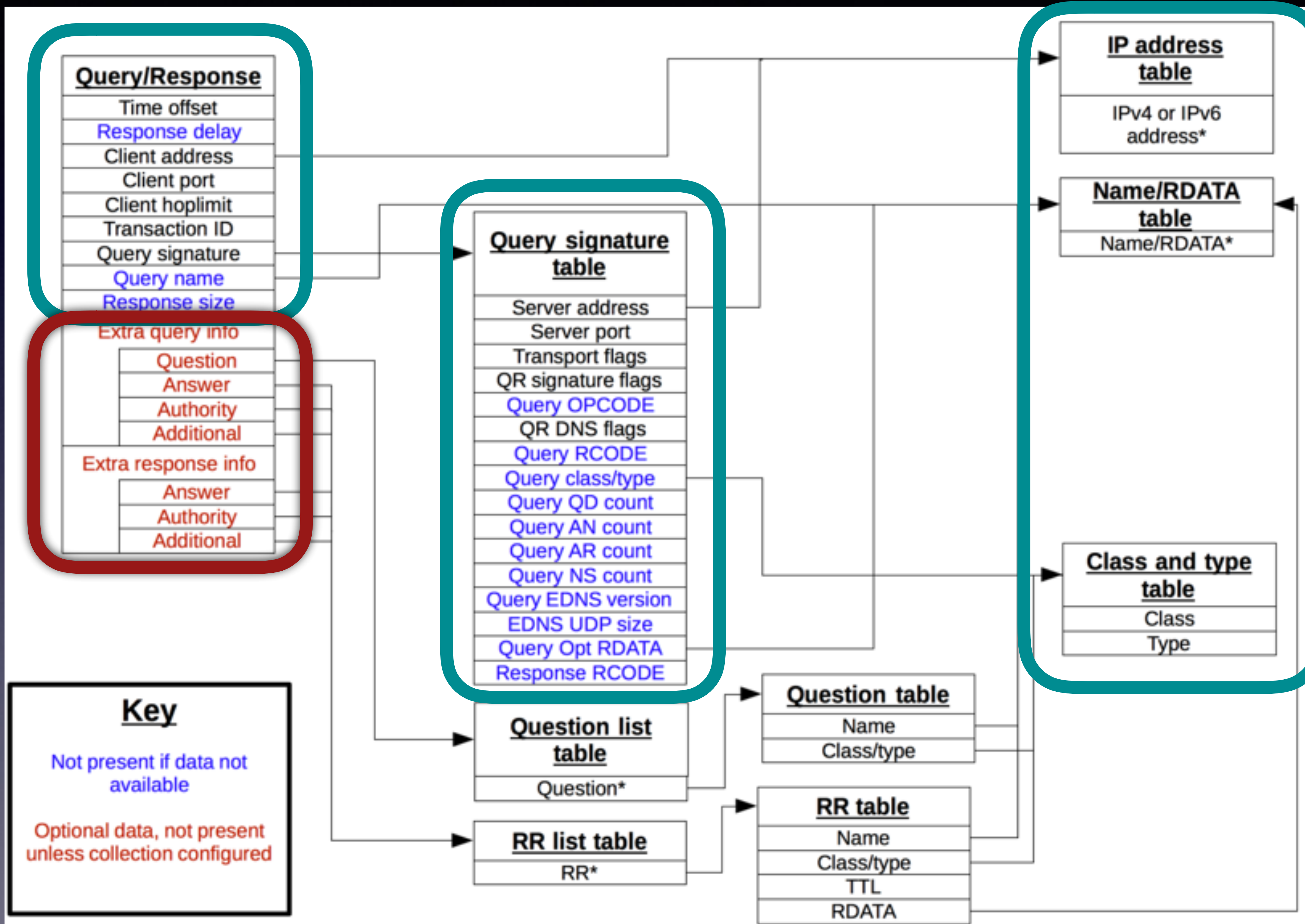

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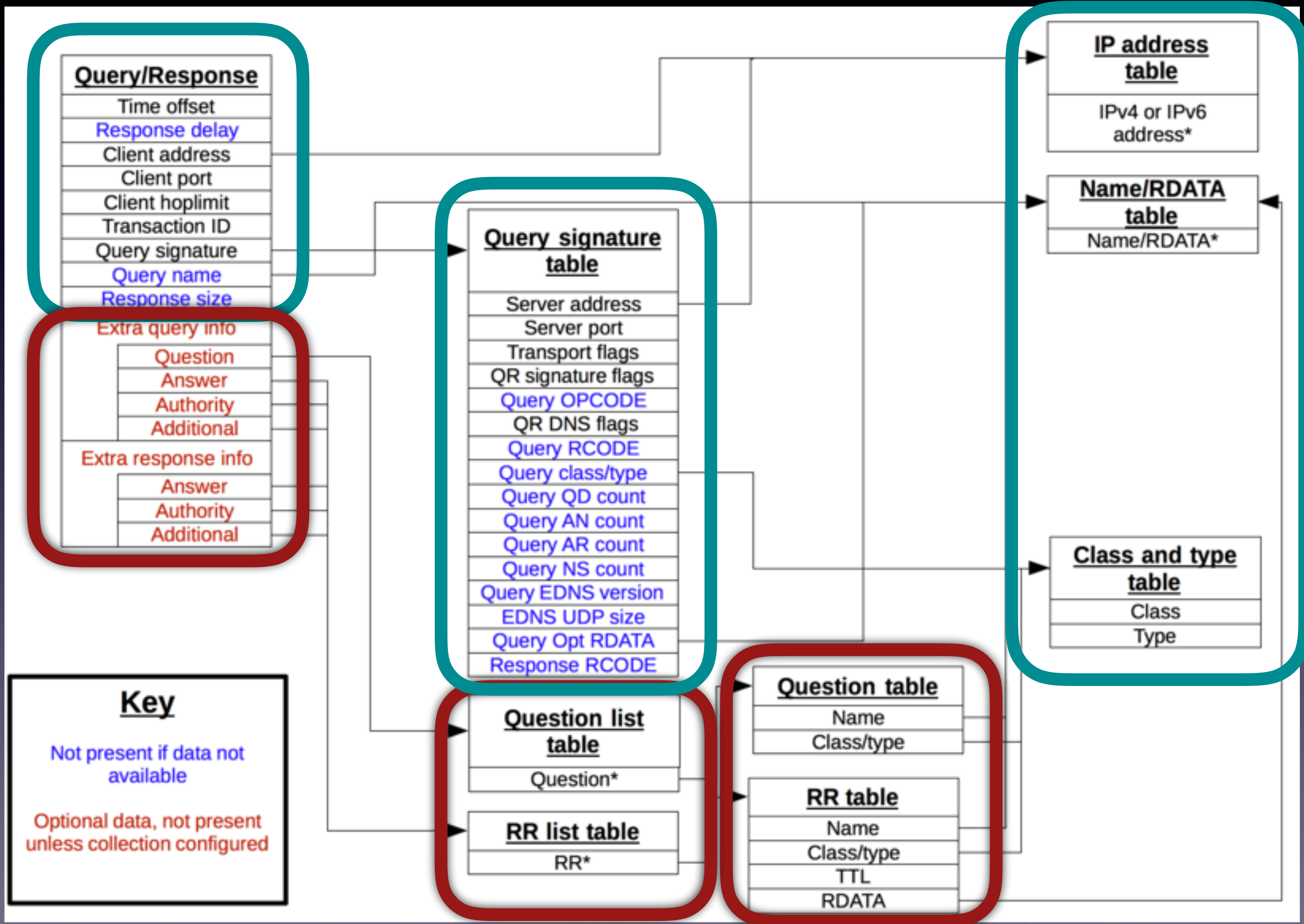


CDDL representation

- Multiple tables - complicated but achieves goals

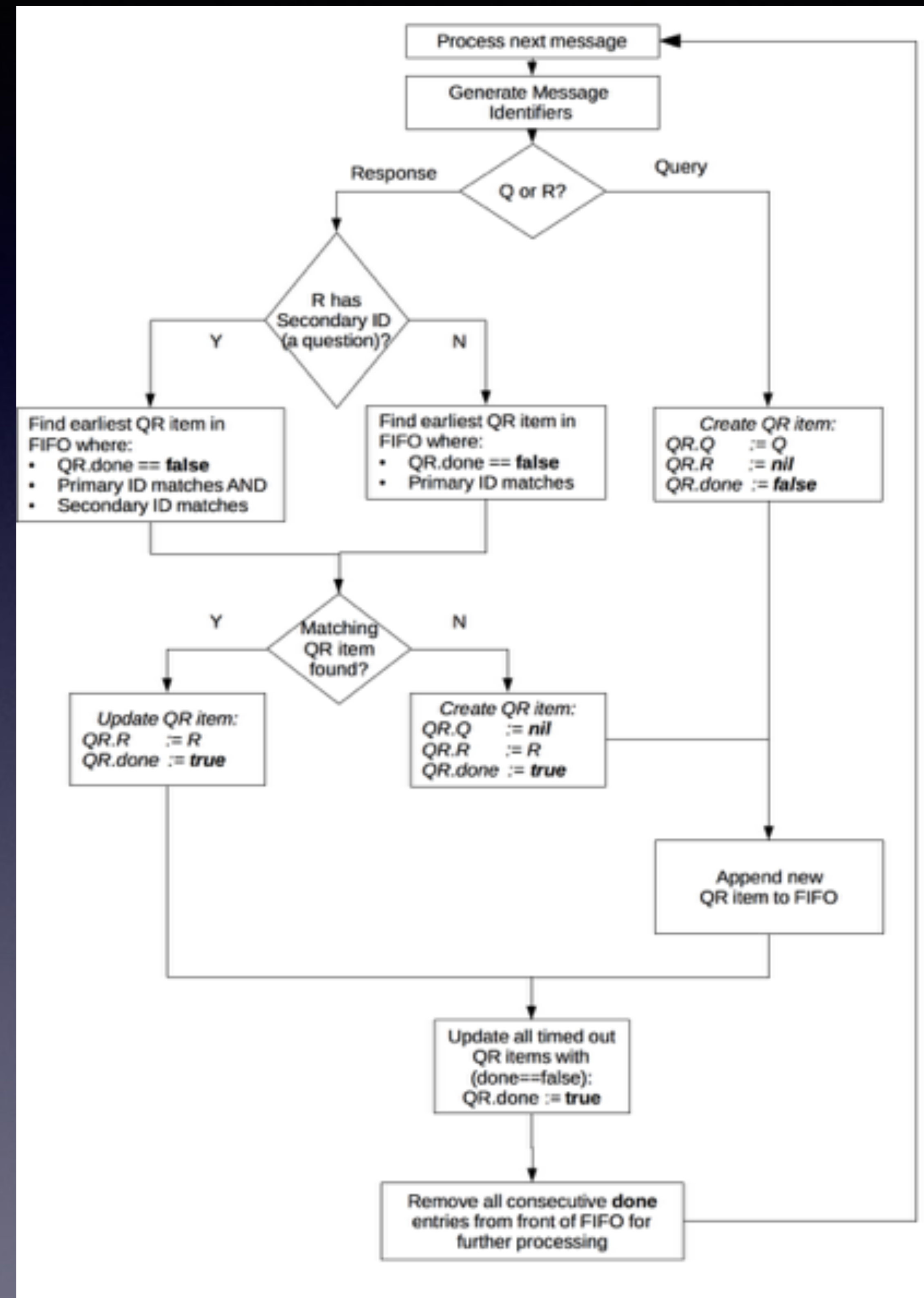
```
QueryResponse = {
      time-useconds           => uint, ; Time offset from start of block
      ? time-pseconds         => uint, ; in microseconds and picoseconds
      client-address-index    => uint,
      client-port             => uint,
      transaction-id          => uint,
      query-signature-index   => uint,
      ? client-hoplimit       => uint,
      ? delay-useconds        => int,
      ? delay-pseconds        => int, ; Has same sign as delay-useconds
      ? query-name-index      => uint,
      ? query-size            => uint, ; DNS size of query
      ? response-size         => uint, ; DNS size of response
      ? query-extended        => QueryResponseExtended,
      ? response-extended     => QueryResponseExtended,
  }
```

Packet Matching Algorithm

Draft contains a non-normative proposal for how to match queries and responses:

Primary key: 6 point tuple of
- IP Addrs, ports, transport, Msg ID

Secondary key: (if present)
- First Question



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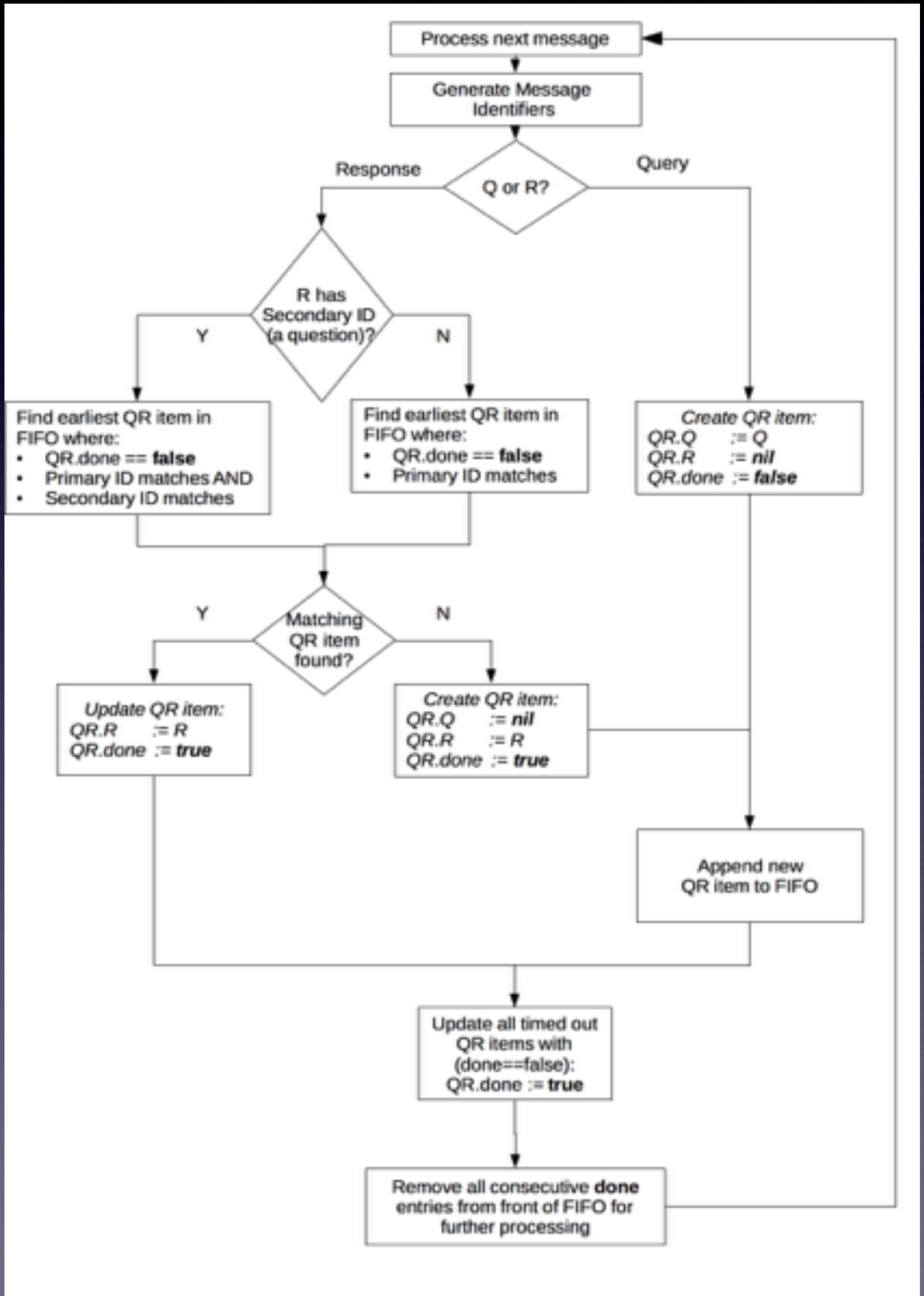
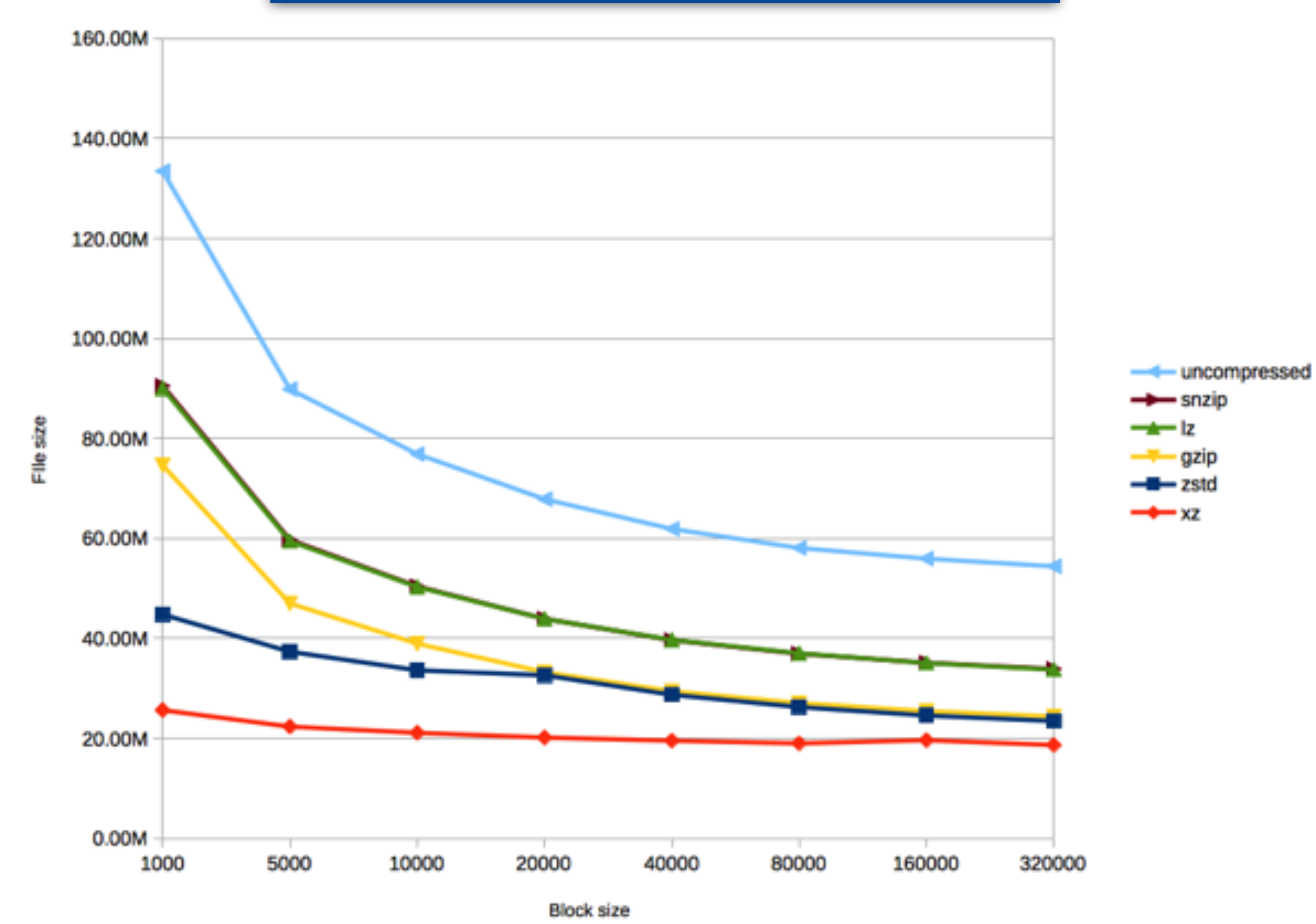
WARNING: Packet capture libraries don't guarantee to return packets in time order



So… Results: Block size

Tests done using sample data from a Root Server

Files size vs block size



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Tests done using sample data from a Root Server

Optimal block size is around 5-10,000 items

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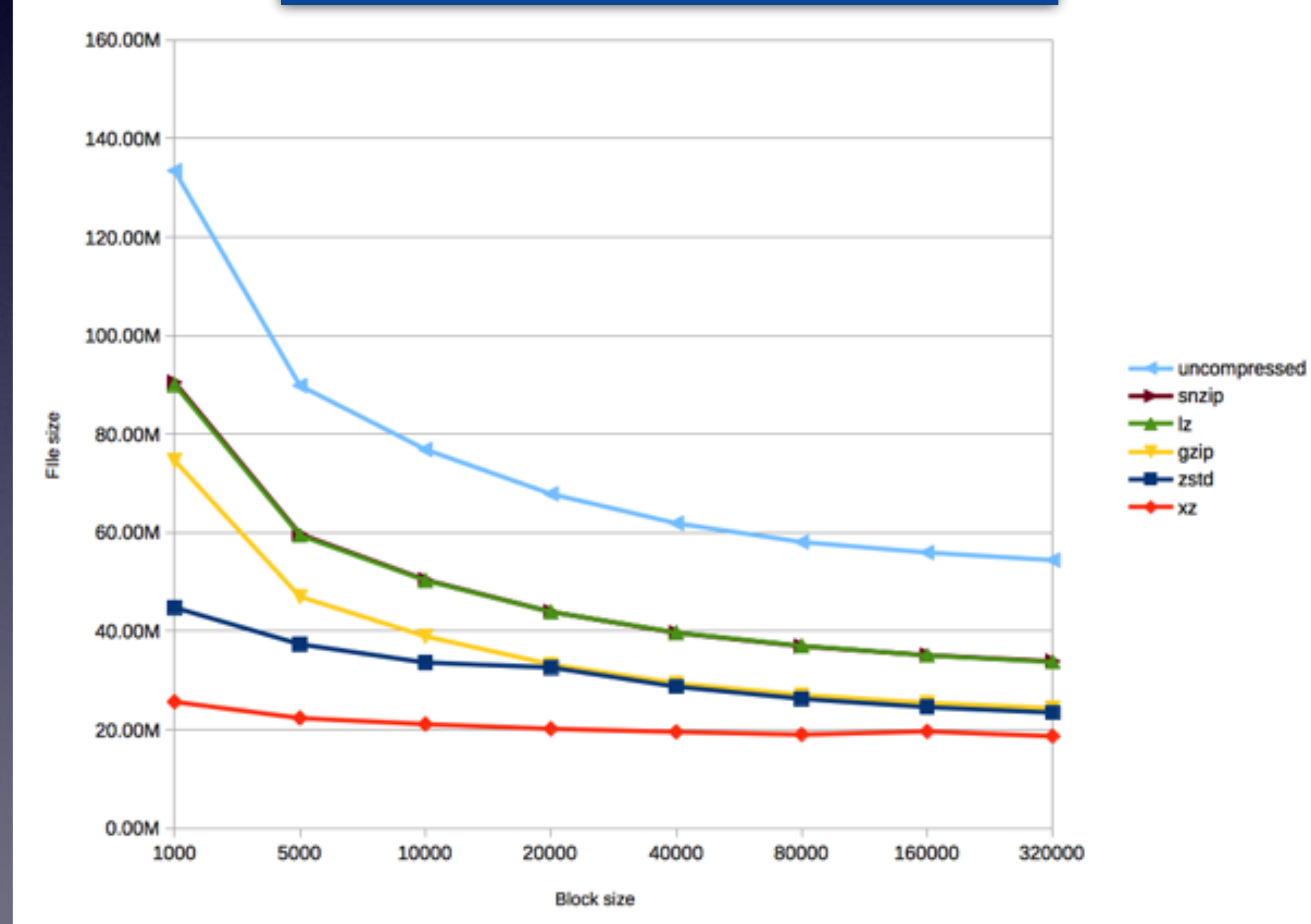

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File size (Mb)	660	75
Compressed with ‘xz -9’ (Mb)	49	18
User time for compression (s)	161	39

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***COMPRESSED SIZE**: C-DNS is 30-40% size of PCAP*

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***COMPRESSED SIZE**: C-DNS is 30-40% size of PCAP*

***COMPRESSION CPU**: C-DNS uses ~25% of PCAP*

Regenerating PCAPs

1. **May not have captured:** Entire message (optional)
2. **Cannot properly reconstruct:**
   - IP Fragmentation, TCP streams
3. **Do not capture:**
   - ICMP, TCP resets (only counts)
4. **Name compression:** Different algorithms used
   - NSD vs Knot detailed in draft

This is a 'lossy' process

DNSOP - Draft Status

- Oct 2016: Submitted first draft
- Nov 2016: IPR disclosure relating to pending patent application (No updates to this since then)
- Dec 2016: Draft adopted by WG
- May 2016: Now on -02 revision, no major issues outstanding (more work on malformed packets)

Implementation Status

- Running code to capture C-DNS and perform lossy reconstruction of PCAP
- Deployed in ICANN operated Root Server in Sept 2016
- Architecture allows for separate capture of ‘ignored’ packets in PCAP files
  i.e. all packets that are not stored in CBOR

Summary

- New DNS traffic capture format progressing as a IETF Proposed Standard
- Significant saving is file size over e.g. PCAP
- Possible to regenerate PCAP in lossy fashion
- Next steps? Consume C-DNS directly for analysis and visualisation

Thank you!

Any questions?