

CS 43: Computer Networks

Writing a DNS Client

9 October, 2020



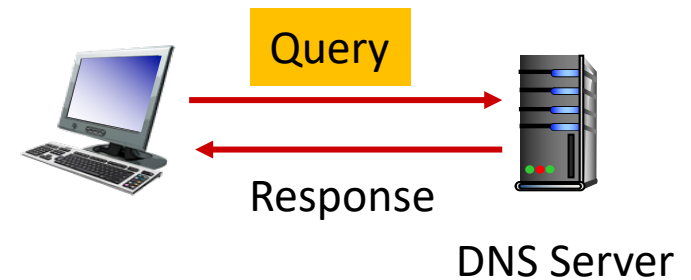
Courtesy: Kurose & Ross, K. Webb, Stanford University

DNS Message Structure

Has the same format for query and response

Header
Question
Answer
Authority
Additional

Query only has the Header and Question portions

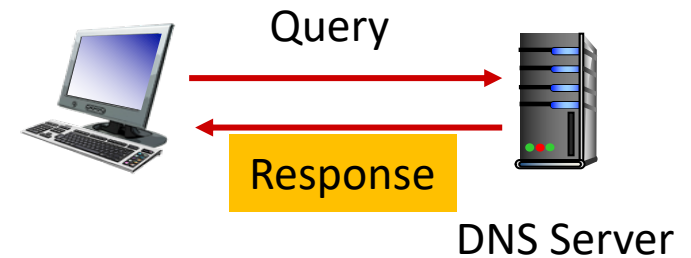


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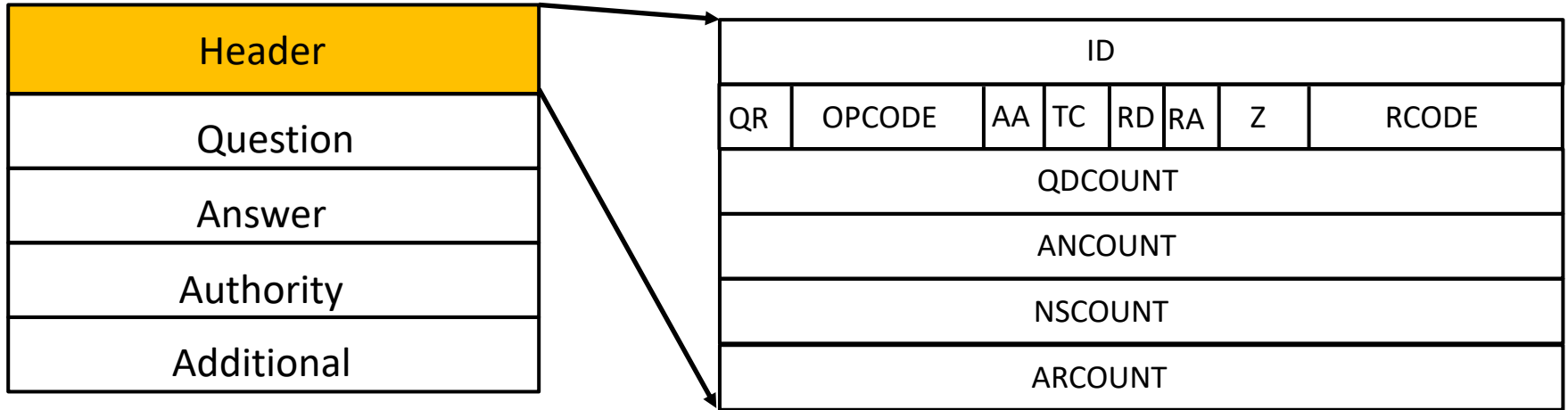
Header
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DNS Message Header

Has the same format for query and response

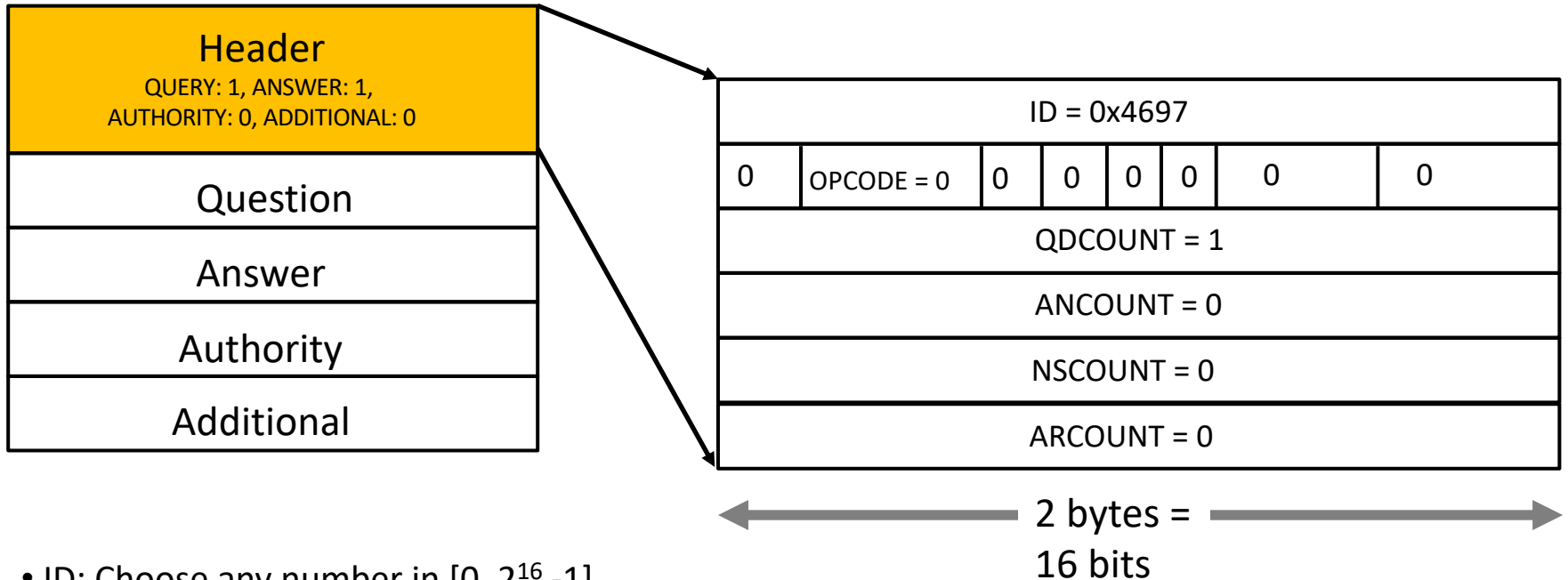


- ID: Choose any number in $[0, 2^{16} - 1]$
- QR: Query = 0, Response = 1
- OPCODE: Standard query = 0
- RCODE: Error Code
- Flags:
 - AA: authoritative server
 - TC: Truncated
 - RD: Recursion Desired
 - RA: Recursion Available

- QDCOUNT: Number of Questions
- ANCOUNT: Number of Answers
- NSCOUNT: Number of Name Server Records
- ARCOUNT: Number of Additional Resource Records

DNS Message Header

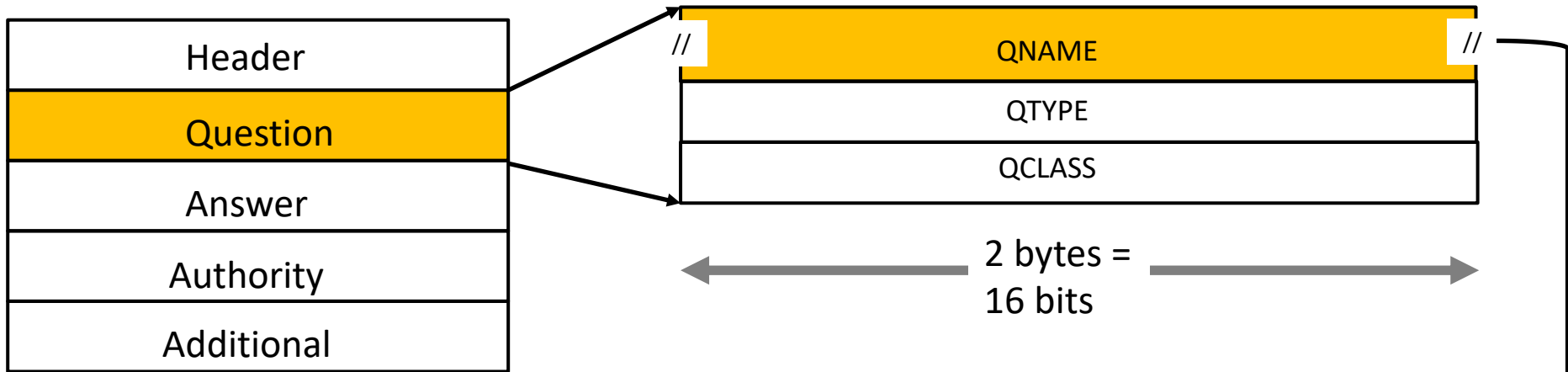
Example query dig demo.cs.swarthmore.edu



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DNS Query format

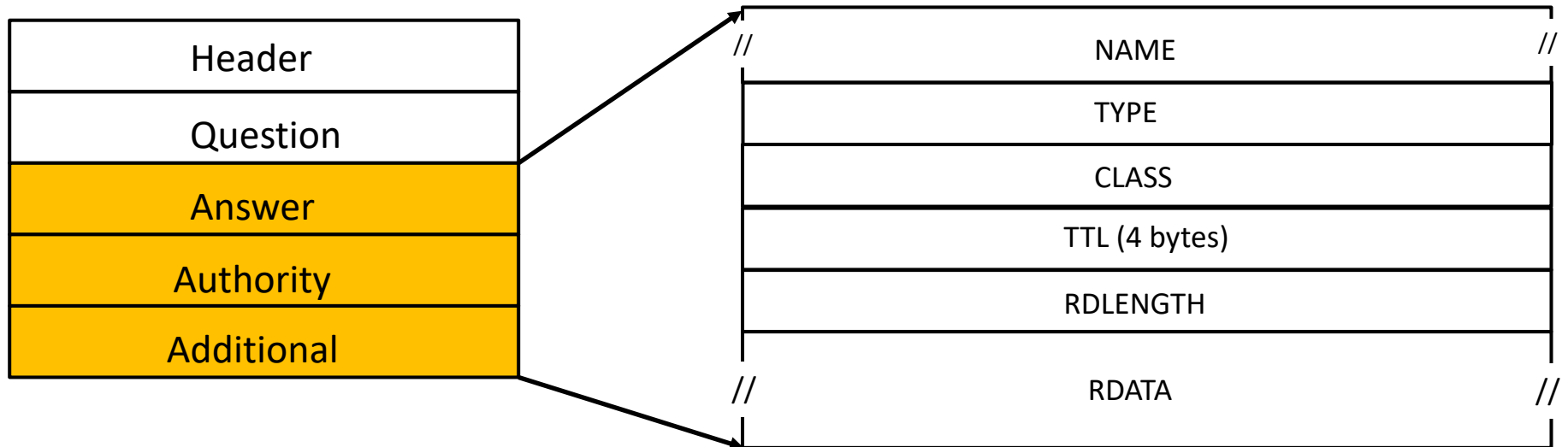


- NAME: Hostname (variable length)
- TYPE: A = 1, NS = 2 , MX = 15..
- CLASS: Internet = 1

//: Represents a variable length field
QNAME= variable length
QTYPE = 2 bytes
QCLASS = 2 bytes

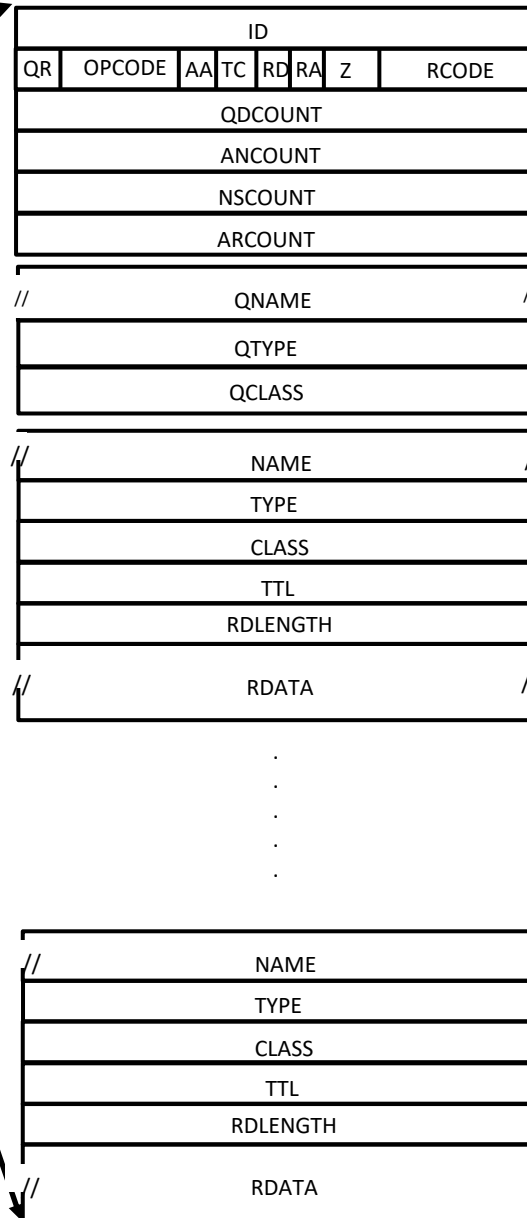
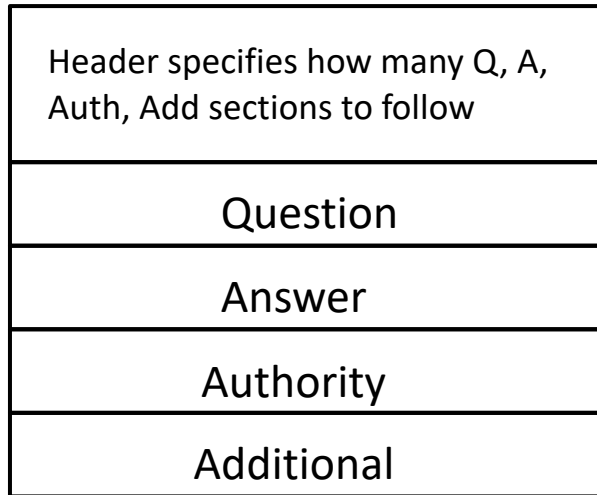
DNS Message Resource Record format

All of the resource records follow the same format



- NAME: Hostname (variable length)
- TYPE: A = 1, NS = 2 ..
- CLASS: Internet = 1
- TTL: time-to-live (seconds)
- RDLENGTH: length of RDATA
- RDATA: record data (variable length)

DNS response format



one header

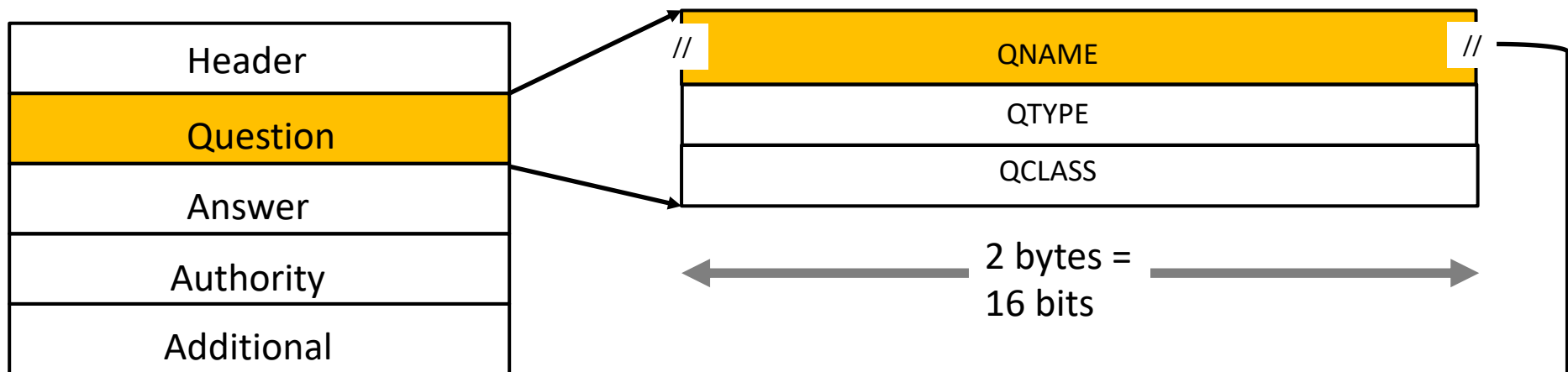
query repeated in response

Resource Records: one or more answers

Resource Records: followed by one or more authority and additional sections

← 2 bytes = 16 bits →

DNS Query format



- NAME: Hostname (variable length)
- TYPE: A = 1, NS = 2 , MX = 15..
- CLASS: Internet = 1

//: Represents a variable length field
QNAME= variable length
QTYPE = 2 bytes
QCLASS = 2 bytes

DNS Name Encoding

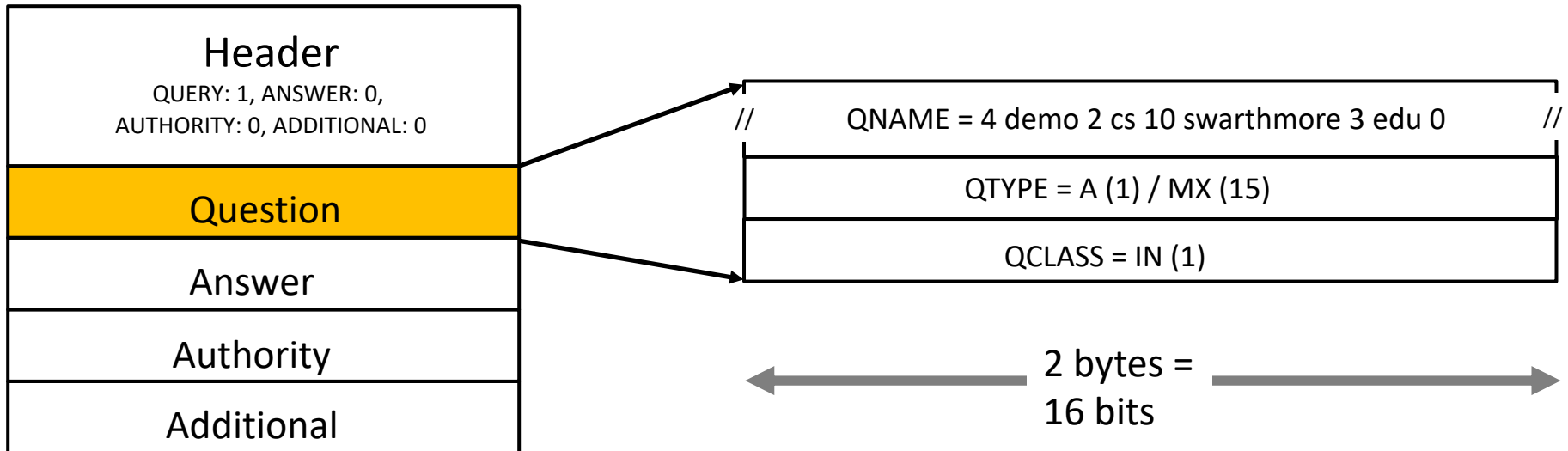


- Names can be long and repeated several times in a packet.
 - Query/Answer
 - NS record/ A record
- Name semantics: Break name into labels
- demo.cs.swarthmore.edu. => 4 demo 2 cs 10 swarthmore 3 edu 0
(nameless root)
 - **length fields** are in binary, text in ASCII
 - e.g. 4 demo in hex = 04 64 65 6d 6f
 - periods in between the hostname (.) are not included

DNS Query format

Example query:

dig +norec demo.cs.swarthmore.edu @ibext.its.swarthmore.edu



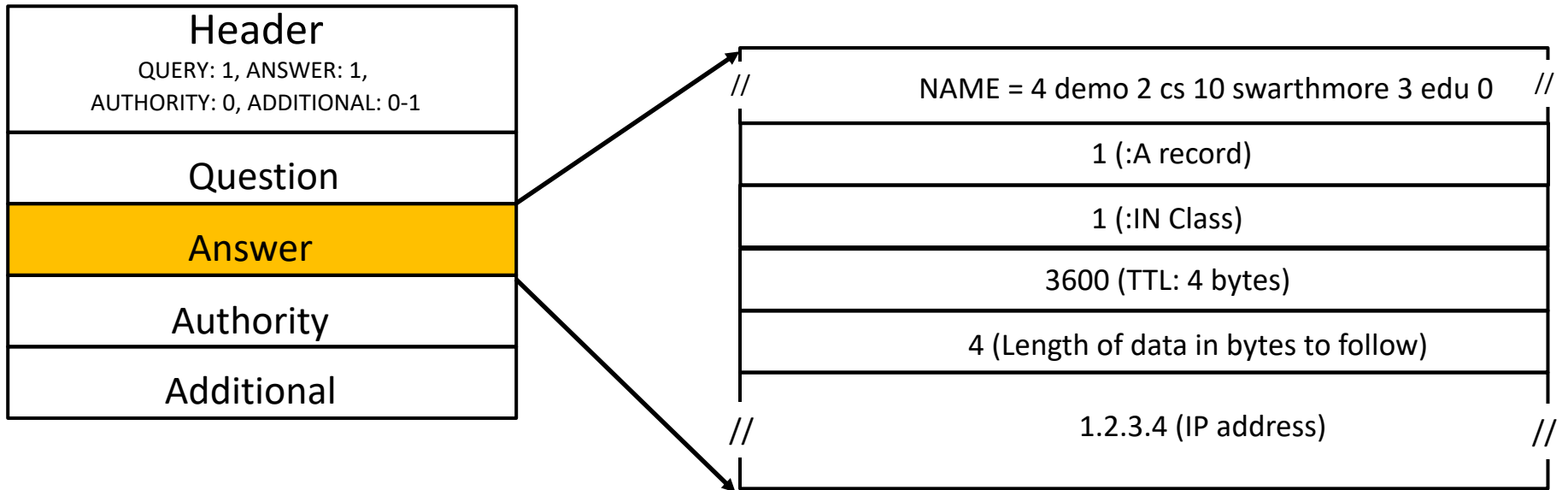
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//: Represents a variable length field
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DNS A Resource Record

Hostname to IP address mapping

dig +nored demo.cs.swarthmore.edu @ibext.its.swarthmore.edu

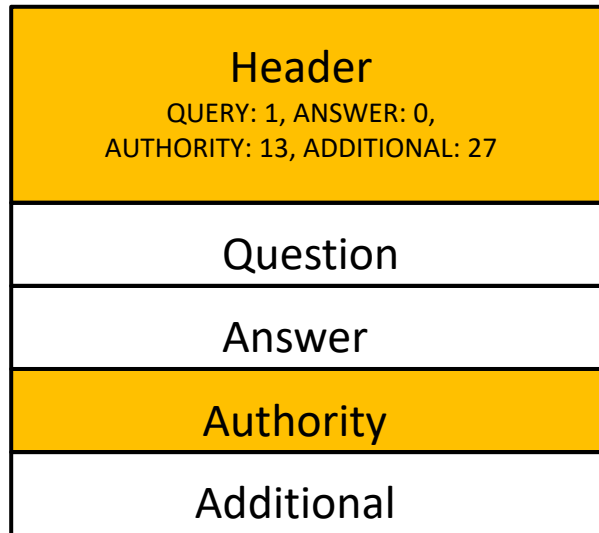


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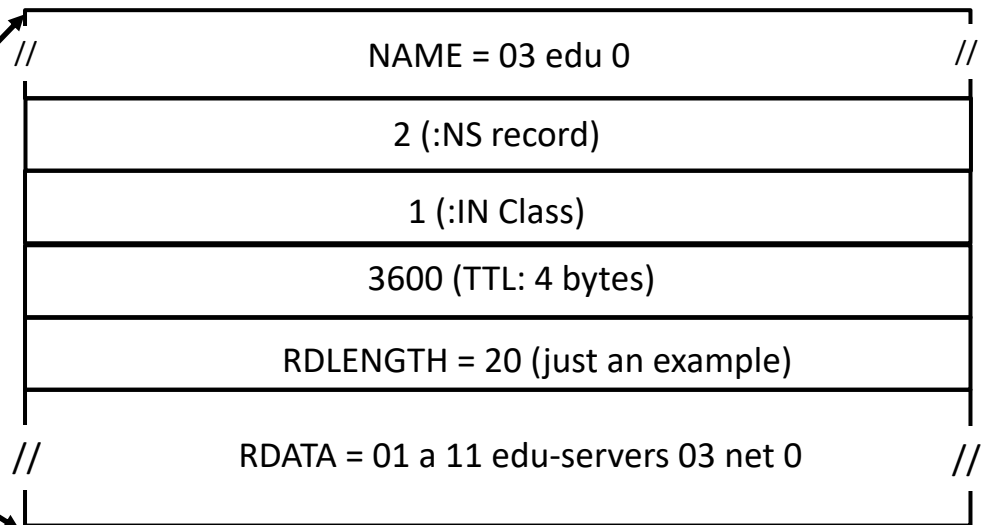
DNS NS Resource Record

Hostname to DNS server mapping

dig +norec demo.cs.swarthmore.edu @a.root-servers.net



Example response returned by root server



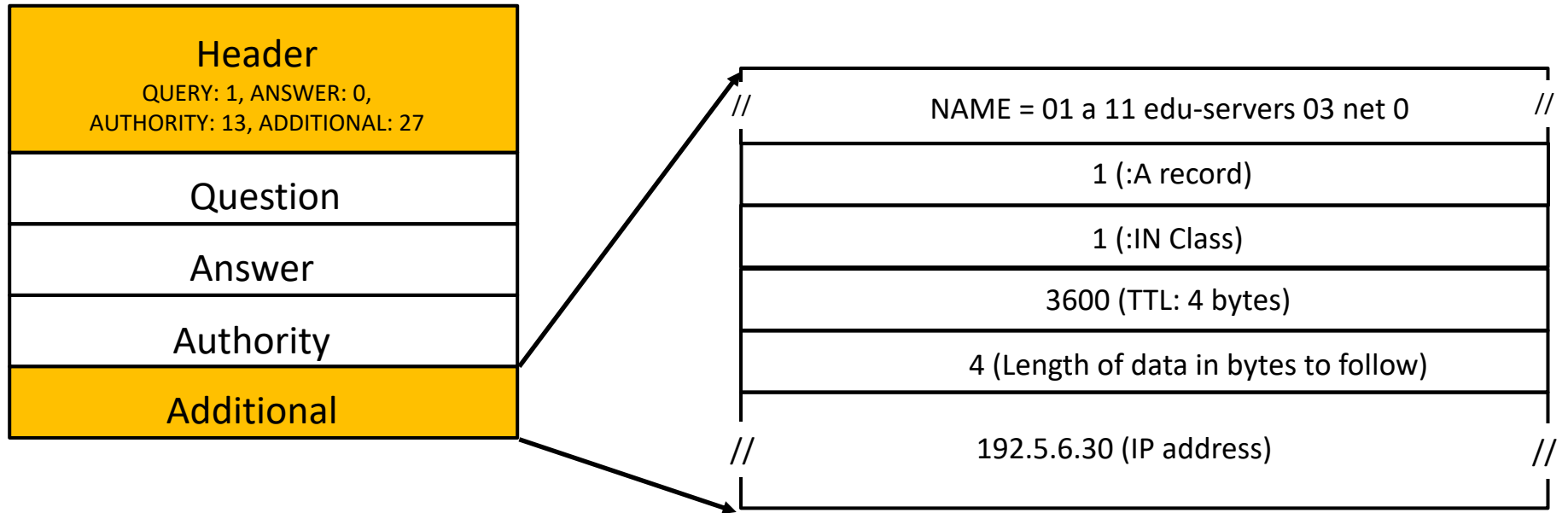
← 2 bytes = 16 bits →

- NAME: Hostname (variable length)
- TYPE: A = 1, NS = 2 ..
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- TTL: time-to-live (seconds)
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DNS NS Resource Record

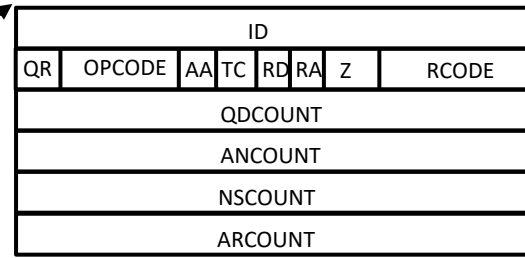
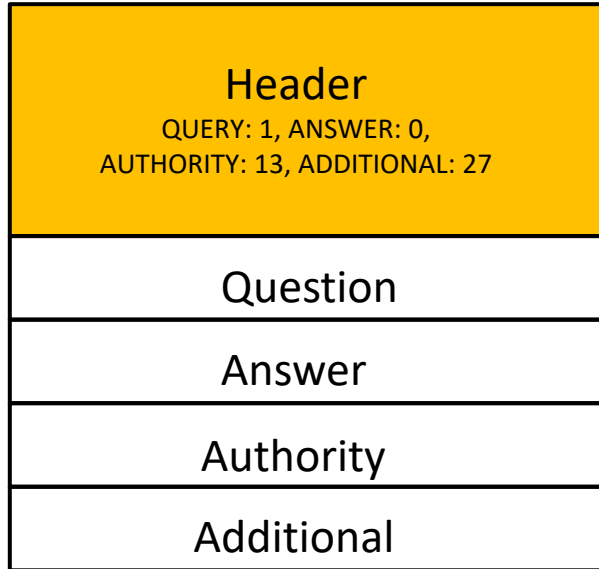
Hostname to DNS server mapping

dig +nored demo.cs.swarthmore.edu @a.root-servers.net

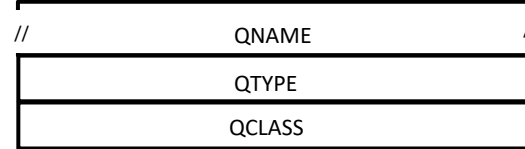


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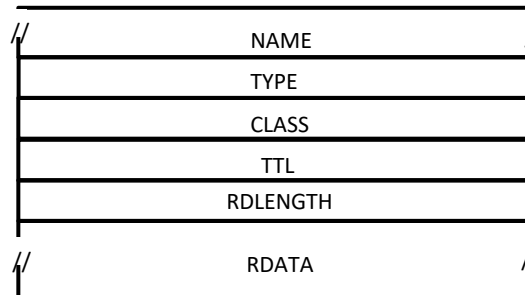
DNS response format



one header

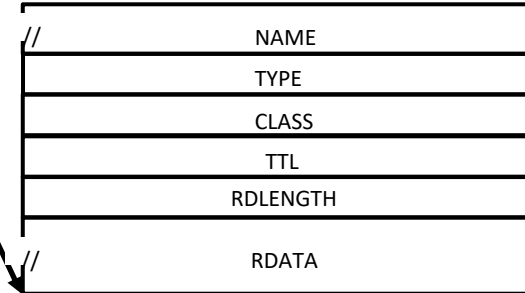


query repeated in response



Resource Records: 13 authority

⋮



Resource Records: followed by 27 additional

← 2 bytes = 16 bits →

DNS Name Compression

slightly more complicated..



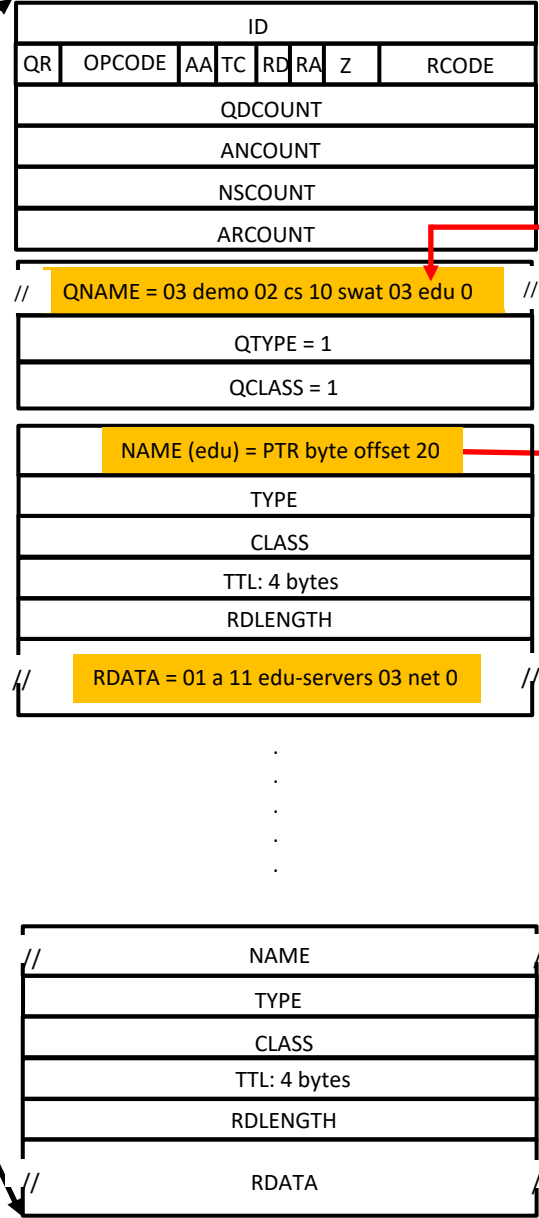
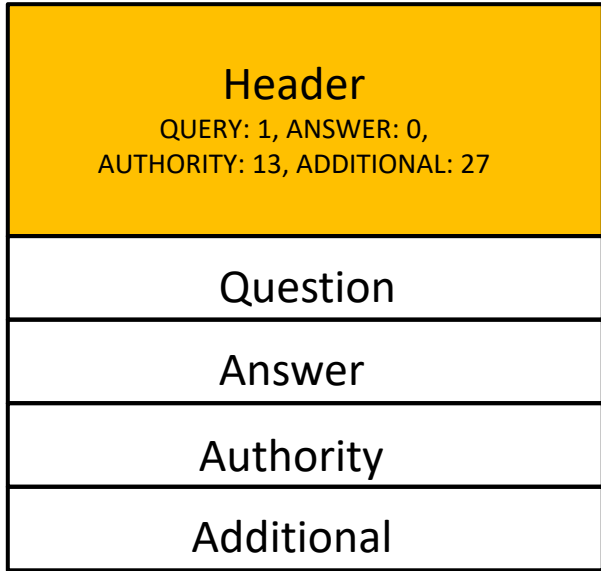
Since names can appear several times in a packet, DNS uses name compression in text fields.

Name compression example:

- Query = demo.cs.swarthmore.edu => 4 demo 2 cs 10 swarthmore 3 edu 0
- Response (say NS record) = edu => 20 (pointer to where edu occurred previously)
 - rather than encode edu as 03 edu 0, DNS will return a pointer to where edu previously occurred in the packet.

DNS name compression

assuming byte 0 = start of DNS



First occurrence of name is formatted as len - domain -len - domain

Subsequent occurrences of the same domain use pointers

Pointers will appear only at the beginning or in the middle of a name. **There will never be more name data following a pointer**

dig +norec
 demo.cs.swarthmore.edu
 @a.root-servers.net

← 2 bytes = 16 bits →

DNS Name Compression

Is it a name or a pointer?



How can you tell what's contained in a variable length name field?

If it is a variable length name:

- a name either follows a <len><sub-domain> format,
- unpacking the first byte would give you the length of the name field that follows.
- you will know that you've reached the end of the name, when the <len> field is zero (length of the nameless root).

DNS Name Compression

Is it a name or a pointer?



How can you tell what's contained in a variable length name field?

If there is a pointer:

- From the [RFC](#) a pointer, is a 2-bytes field, 16 bits in length, and has the format shown below:

```
ascii art format:
index:  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
      +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
      | 1| 1|                |
      +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

- i.e, first two bits are 1 1
- the next 14 bits specify the offset (from the beginning of the response).

DNS Name Compression

Is it a name or a pointer?

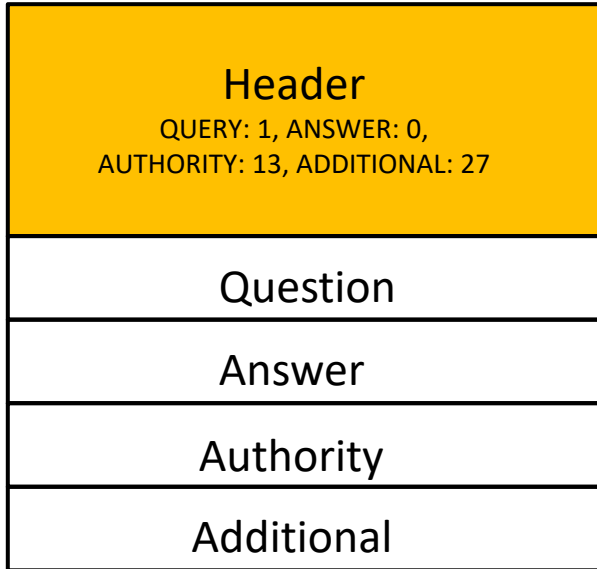
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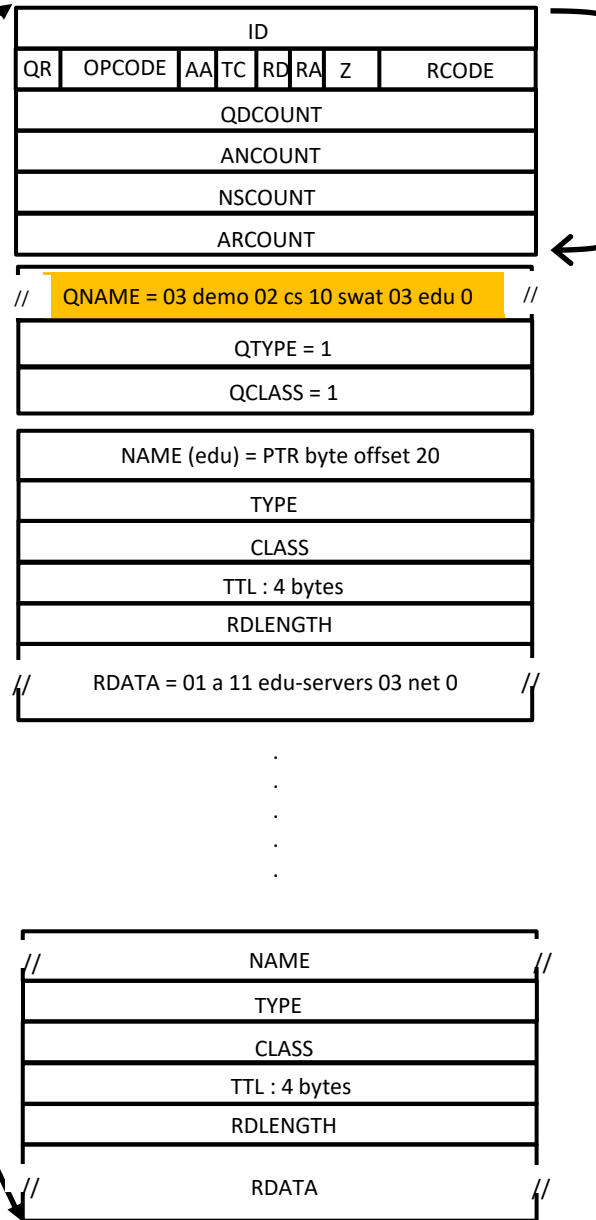
```
ascii art format:
index:  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
      +-+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
      | 1| 1|           |                                     |
      +-+---+---+---+---+---+---+---+---+---+---+---+---+---+---
```

- i.e, first two bits are 1 1
- the next 14 bits specify the offset (from the beginning of the response).
- to figure out if the first byte is a pointer:
 - *use bitwise operations (& |) to flip individual bits such that you return 11000000 only if the first two bits of the first byte are 11.*
- if it is a pointer, extract the entire 2 byte pointer
 - to get the offset, you'll again need bitwise operations *to only return the 14 bits and exclude the first two bits.*

DNS fields you should be able to parse



```
dig +nored  
demo.cs.swarthmore.edu  
@a.root-servers.net
```



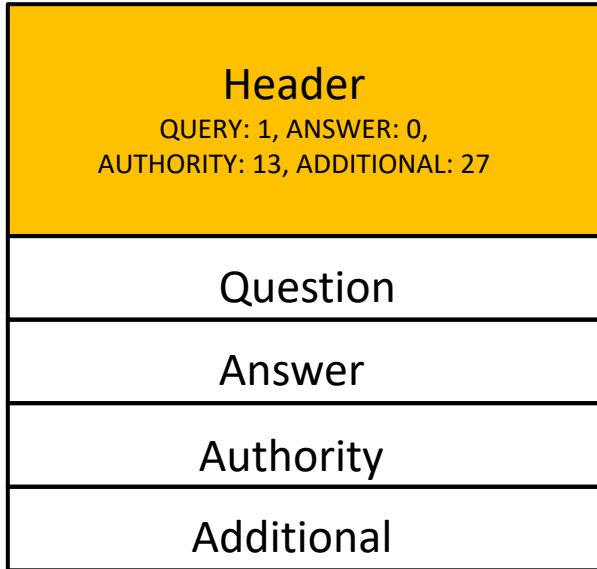
Fixed length fields

Variable length fields

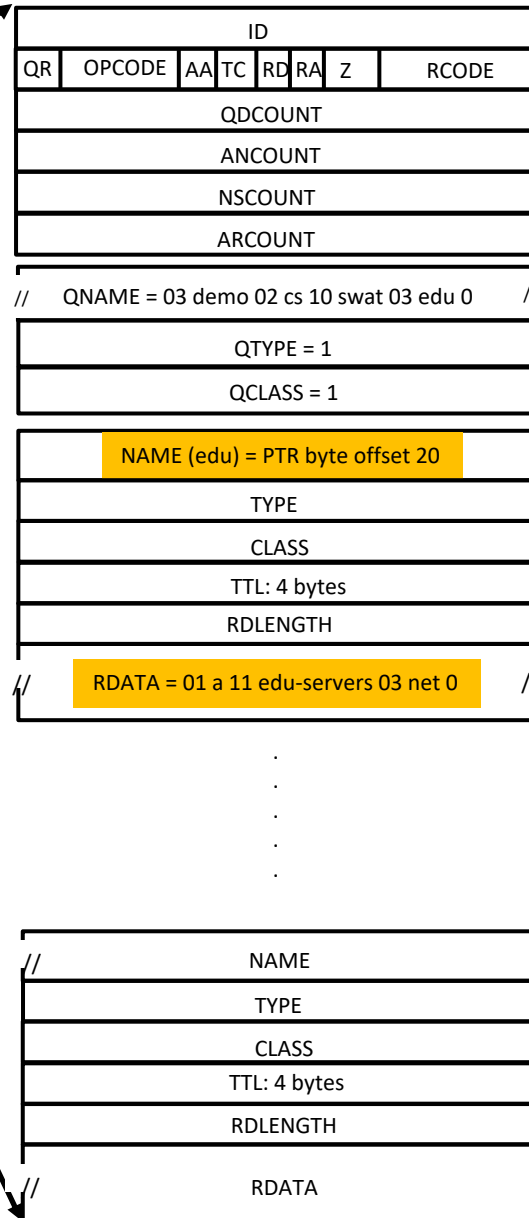
Keep an index of where you are at in the DNS response

← 2 bytes = 16 bits →

DNS fields you care about



dig +norec
 demo.cs.swarthmore.edu
 @a.root-servers.net



RCODE= start of DNS

All the count values .. tells you what's coming next.

Skip past the query in response

loop through RRs based on type. extract relevant details.

you care about name -> data mapping (Name, RDLENGTH, RDATA)

can skip past type, class TTL

← 2 bytes = 16 bits →