A software-based approach to reproduce and detect flooding attacks against DNS

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Some keywords

- Network traffic online analysis
- Countermeasure flooding attacks
- Software approaches
- Statistical tools
- Distributed data sources (for future work)

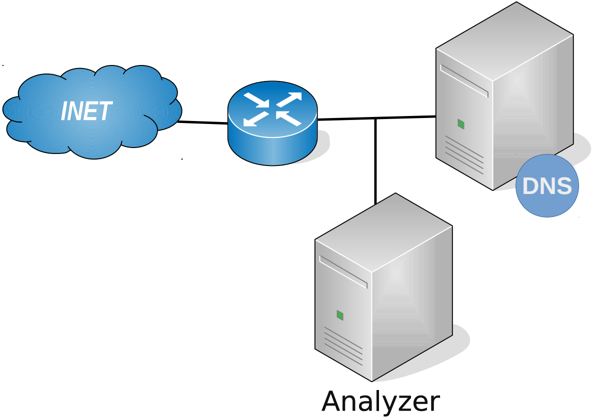
Problem: flooding attacks against DNS infrastructure

- Random qname against French servers, September 4th 2014.
  `https://indico.dns-oarc.net/event/20/session/3/contribution/37`

Figure: Wallis-et-Futuna (.wf)

Image: (C) Dr. Angela Kepler `http://www.pbif.org/images`

A software-based DNS flooding attack detection testbed



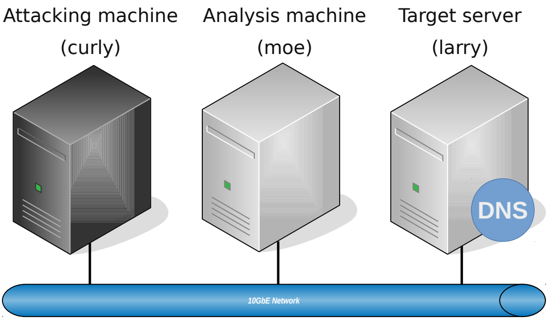
- How to help resilience of DNS infrastructure?

Outline

A software-based DNS flooding attack detection testbed

- Goal: Detect and countermeasure flooding-DDoS attacks
  - Reproduce attacks - Generate traffic
  - Read and process packets on the fly
  - Future: classify
- Flexible and reliable tools to analyse DNS traffic at Nx11Mpps.
- We want flexibility! $\Rightarrow$ Highest abstraction level
  - Commodity hardware
  - Software network frameworks

A software-based DNS flooding attack detection testbed



- Thanks to CNRS INS2I Projet Exploratoire Premier Soutien (PEPS) Sécurité informatique et des systèmes cyberphysiques (SISC) 2016.

Hardware environment

- Dell 7X00 Precision workstations
- Dual socket. Intel(R) Xeon(R) CPU E5-2630 v3 @ 2.40GHz
- From 16GB to 64GB RAM
- Debian Jessie
- Intel NICs:
  - Dual SFP+ port X520-DA2
  - Dual RJ45 port X520-TA2.
  - Dual QSFP+ port XL710-QDA2

Software network engines for commodity hardware

Software network engines for commodity hardware

Alphabetically sorted:

- Data Plane Development Kit DPDK (Intel)
  - Strong support from industry
- High-performance Packet CAPture HPCAP (Moreno et al., UAM) [MRdR+15]
  - Specially designed for capture and to avoid packet losses.
  - Academic work that needs a stable release.
- PFQ (Bonelli et al., Univ. of Pisa) [BPGP12]
  - Uses the Intel vanilla driver, relying on multi-core processing.
  - Unable to handle 10Gbps on a single core.
- PF_RING (Deri et al., Ntop) [PFR]
  - Zero-copy version needs a commercial license.

Outline

Shield of Perseus (SOP)

- `http://www.bortzmeyer.org/files/jres2013-dos-article.pdf`
- Written in C
- Relies on standard Linux NAPI
- Running on Linux:
- ~520Kpps fully-random requests @ 2200Mhz single-core
  - Increases when using several threads

MoonGen and libmoon

- Paul Emmerich, TUM [EGR+15]
- LuaJIT interface to DPDK: scripts control packet generation
- Delegate rate control and timestamping to hardware
- `https://github.com/emmericp/MoonGen`
- `https://github.com/libmoon/libmoon`

Reproducing DNS flooding attacks

Requirements

- Randomise different bytes/fields.
  - Source IP addresses
  - TTL
  - qname (varying lengths)
  - Varying DNS query data
  - EDNS, UDP buffer size
  - . . .
- Reproduce:
  - Random qnames
  - Reflect-and-amplify
  - . . .
- Easily take into account other attacking strategies
- No need to highly accurate timestamping/control

gGALOP: our DNS-packet generator

- gGALOP (gGALOP Generates A Lot Of Packets)
- On top of MoonGen + DPDK
- *Reproducing DNS 10Gbps flooding attacks with commodity-hardware*, TRAC-IWCMC 2016

To give it a name is more difficult than DNS-flooding

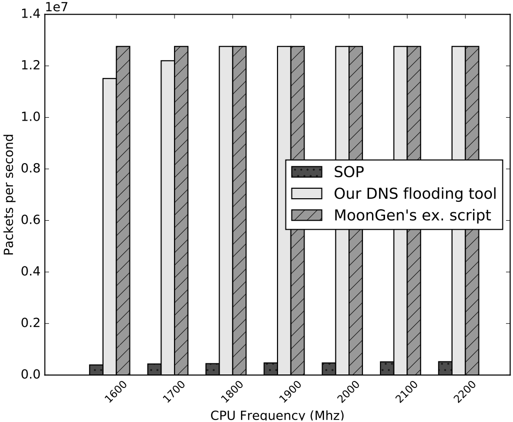
- ~320-line Lua(JIT) script
- ~11M full-random pps per CPU core
- Batch processing

```
function loadSlave(...)
    local mem = memory.createMemPool(function(buf)
        buf:getDnsPacket(ipv4):fill{
            ip4Src=genIPv4AddSource(),
            ip4Dst=dnsServerIP,
            ...
          dnsMessageContent=genBody()}
  end)

    while dpdk.running() do
        local bufs = mem:bufArray(MAX_BURST_SIZE)
        bufs:alloc()
        ...
        sent = queue:send(bufs)
```

CPU Requirements to saturate a 10 GbE link

- Shield of Perseus (SOP)
- gGALOP
- MoonGen's example/tx-multi-core.lua (simple, non-random packets)

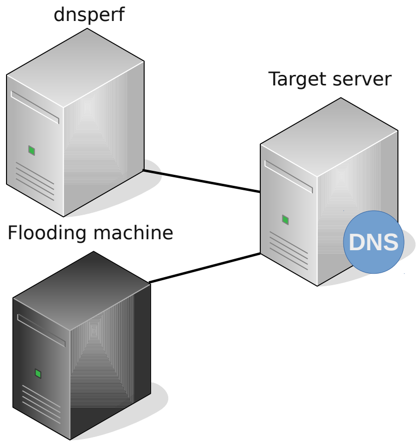


Generation results

- Solution: DPDK+MoonGen+Lua scripts
- Generating packets controlled by Lua scripts
  - Then: highest possible level of abstraction
  - Highly flexible
- Succesfully reproduce random qnames and reflect-and-amplify
- Able to scale to Nx11Mpps:
  - Saturate 3x10GbE ports on a quad-core CPU

DNS Servers versus DNS flooding

- We don't have a 10GbE switch (yet)



DNS Servers versus DNS flooding

- DNS serving a 3M-record zone.
- PowerDNS
- ISC BIND
  - Listening on both ports (Intel X520-DA2)
  - Single core
- dnsperf while flooding the server
  - gGALOP (11Mpps)
  - SOP (665Kpps)

DNS Servers versus DNS flooding

- PowerDNS:
  - SOP: 20% answered requests
  - gGALOP: 30% answered requests
- BIND resisted!
  - SOP: 95% answered requests
  - gGALOP: 100% answered requests
- SOP has a stronger impact!

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  - 324883 (gGALOP)
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  - The rest was lost between the interface and the kernel

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- Same machine serving on multiple interfaces is a good idea?
- Slower attacks can be more succesful?

Outline

Current challenge: how to identify trouble sources?

- Capture and analyse traffic
  - What approach scores highest at minimizing packet drops?
- Rely on libmoon (base of Moongen)
- Statistics-based detection

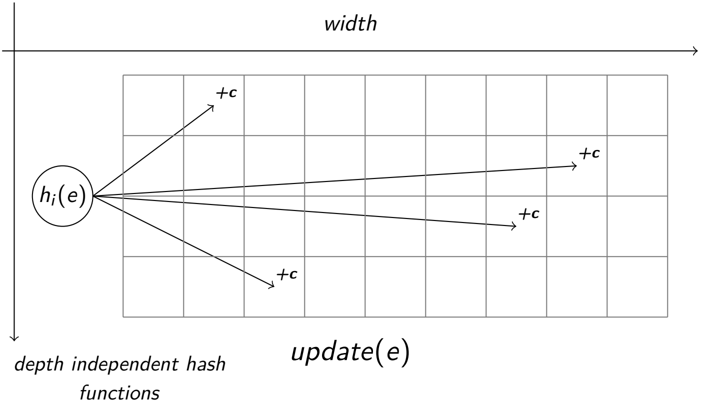
Current challenge: how to identify trouble sources?

- Identify Heavy Hitters
- **Counting** / keeping statistics about:
- Most frequent source IP address
  - IPv4 (2**32)
  - IPv6 (2**128) Tests are coming soon :-)
- Most frequent domains
  - Random, varying length (undetermined)

Statistical tools

- Cormode and Muthukrishnan, *Count-Min Sketch* [CM05]
  - Fixed and controlled size table
  - (Non-reversible) hash functions
- Misra & Gries, *Finding Repeated Elements* [MG82]
- Entropy deviation
  - Keisuke Ishibashi & Masaharu Sato, Hierarchical Aggregate Entropy. DNS-OARC 2010-02 `https://www.dns-oarc.net/files/meeting-201002/4_Keisuke_Ishibashi.pdf`

Count-Min Sketch



- $\epsilon - \gamma$ approximation
- Count every x seconds
- Analyse 11Mrps on 4 cores (Intel E5-2630 v3 @ 2.40GHz)

Estimate most frequent domains

```
misragries ← mgInit(k)
sketch ← cmsInit(epsilon, gamma)
for packet in rxBuffer() do
    {Get qnames from DNS payload}
    for qname in getQNAMEs(packet) do
        trimmedQN ← trimQNAME(qname)
        misragries.count(trimmedQN)
        hashedQN ← hashString(trimmedQN) {Hash into int}
        sketch.update(hashedQN)
    end for
end for
```

Demo time! Counting Rx'ed packets per domain

Demo time! Counting Rx'ed packets per domain

```
Total counts (requests per domain):
larry.3s.       :       19999880
curly.3s.       :       19999881
hola.org.       :       19999880
flooding.evil.  :       19999885
moe.3s.         :       19999880
example.com.    :       19999886
----
total:  119999292
total packets received by device:       120000000
```

Ethical concerns

- Access to payload (and how to analyse encrypted DNS?)
- Not logging
- Avoid linking IP sources to queries
- What else?

Thanks to

- CNRS PEPS 2016 Program
- Fondation Carnot
- DNS-OARC
- RACI :-)
- libmoon and MoonGen authors

Thanks for your attention

Feedback?

References I

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Limited by random fields?

- Using a single core, CPU @1.6Ghz
- Randomising fields does not strongly impact performance