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TBD: To Block connection to malicious host by using “DQB” and "Shutdowner"

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Index

- Preliminary
- Decepting and Security live next door to each other
- Simple Specification/Architecture
- Simple Operation
- Jackpot!
- Conclusion

Preliminary: Our infrastructure Overview

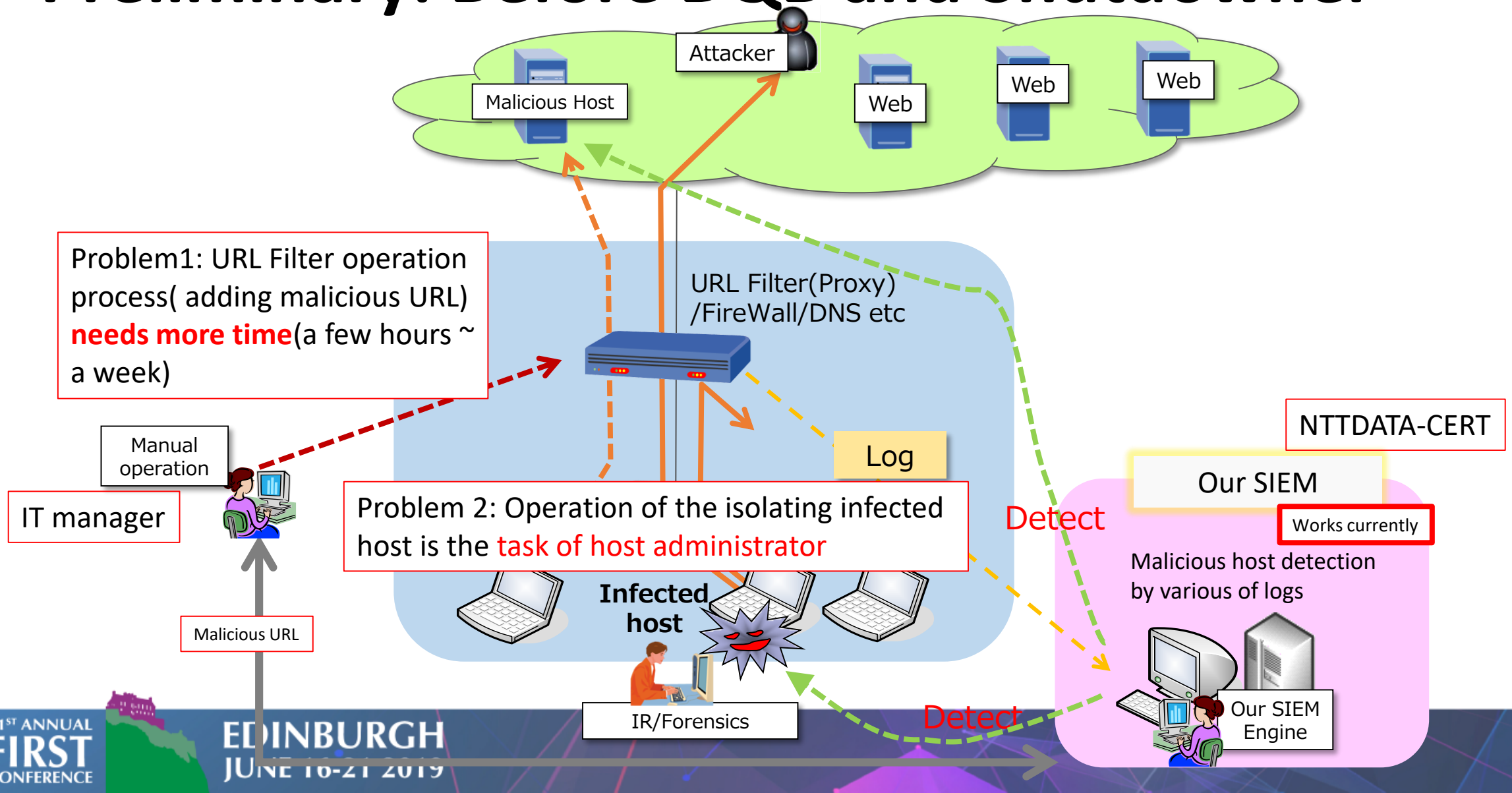
- We use large amount of computers(above **20k～30k, Windows run most of computers**)
  - Many of them:**Windows Embedded(without MS17-010 patches)**
- We have deployed and been operating Security Solutions as below:
  - Firewall(by security vendor)
  - Quarantine(Patch Management and Internet Access Control) (by security vendor)
  - USB port control (by security vendor)
  - URL filter (by security vendor)
  - End Point Security Software like virus scanner (by security vendor)
  - SIEM(by ourselves)
- Too many blackbox ☹

Preliminary: Responding to malicious URL

- Find suspicious URL by our SIEM or others
  - Consider whether URL is malicious or not(<1h)
  - Send URL Filter operators the request adding malicious URL(s) to URL filter
  - (wait for a **few hours**)(>2~3h)
    sometimes waits **a few days**(<1w)
  - Done

- If malicious URLs are found oftenly, URL Filter operators receive requests oftenly
  - Too heavy to process requests

Preliminary: Before DQB and Shutdowner



Decepting and Security live next door to each other

We Decept a Certain kind of Responses for Keep Security

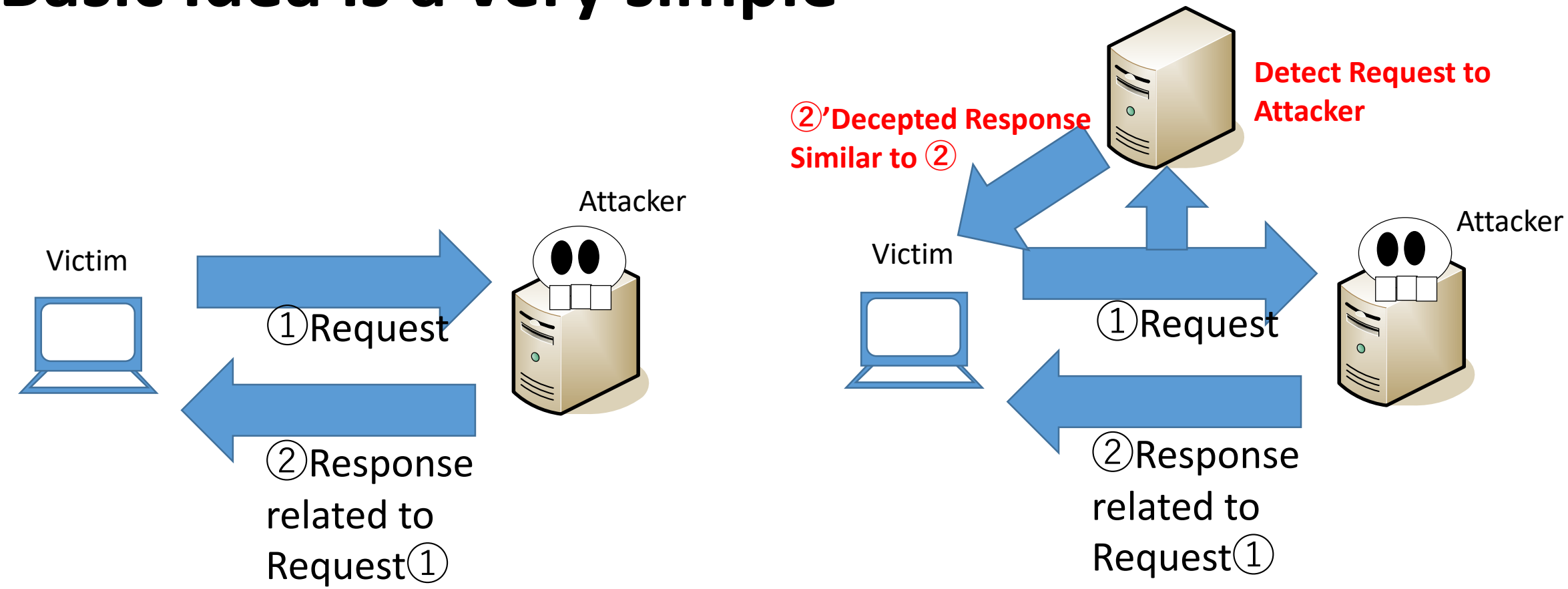
Deception and Security

- Deception can make **attackers to spend their time/costs for attacks more**
- DQB and Shutdowner are system to decept
  - **DQB(DNS Query Blocker)**: DNS response deception, don't block DNS Query☺
  - **Shutdowner**: TCP response deception
- Deploying these systems to:
  - DQB: same segment that the **cache DNS in NTT DATA is placed to decept efficiently**
  - Shutdowner: same segment of the **Proxy Load Balancer to stop C&C communication**

Simple Specification/Architecture

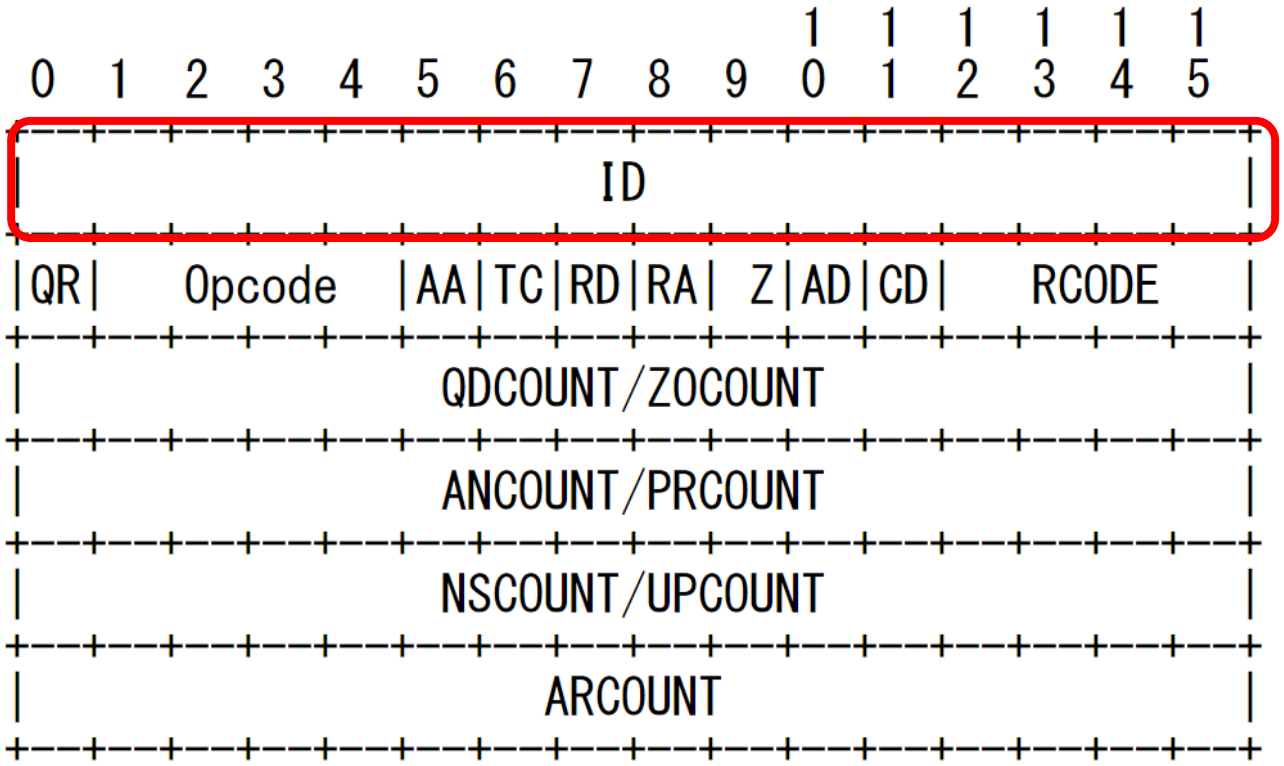
Complex Specification/Architecture makes work slower ☹

Basic Idea is a very simple



- If ②' is received by Victim faster than ②, **② from Attacker is ignored**

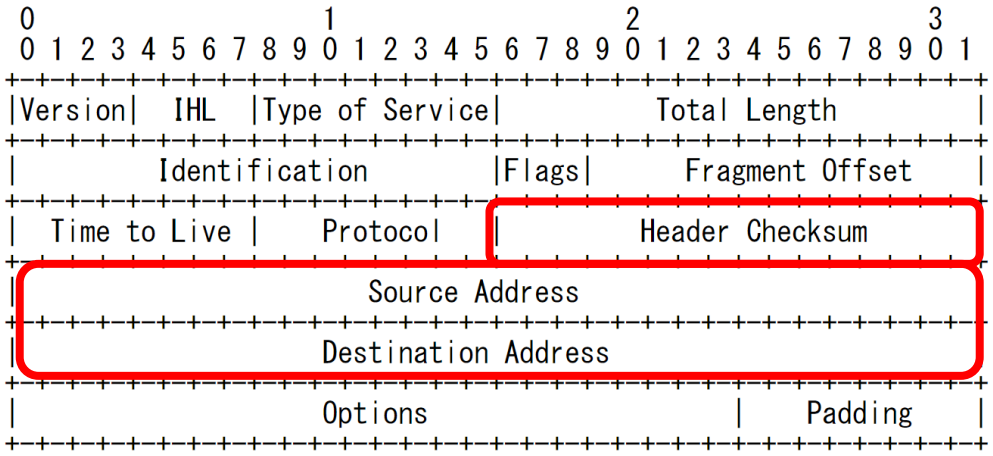
To Decept DNS Response: Easy and Simple(1/2)



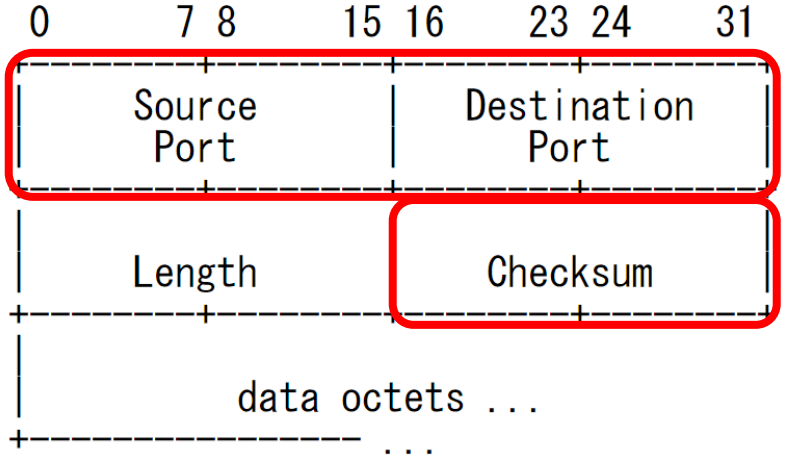
The ID field identifies the query and is echoed in the response so they can be matched.

Reference: RFC6895 Domain Name System (DNS) IANA Considerations

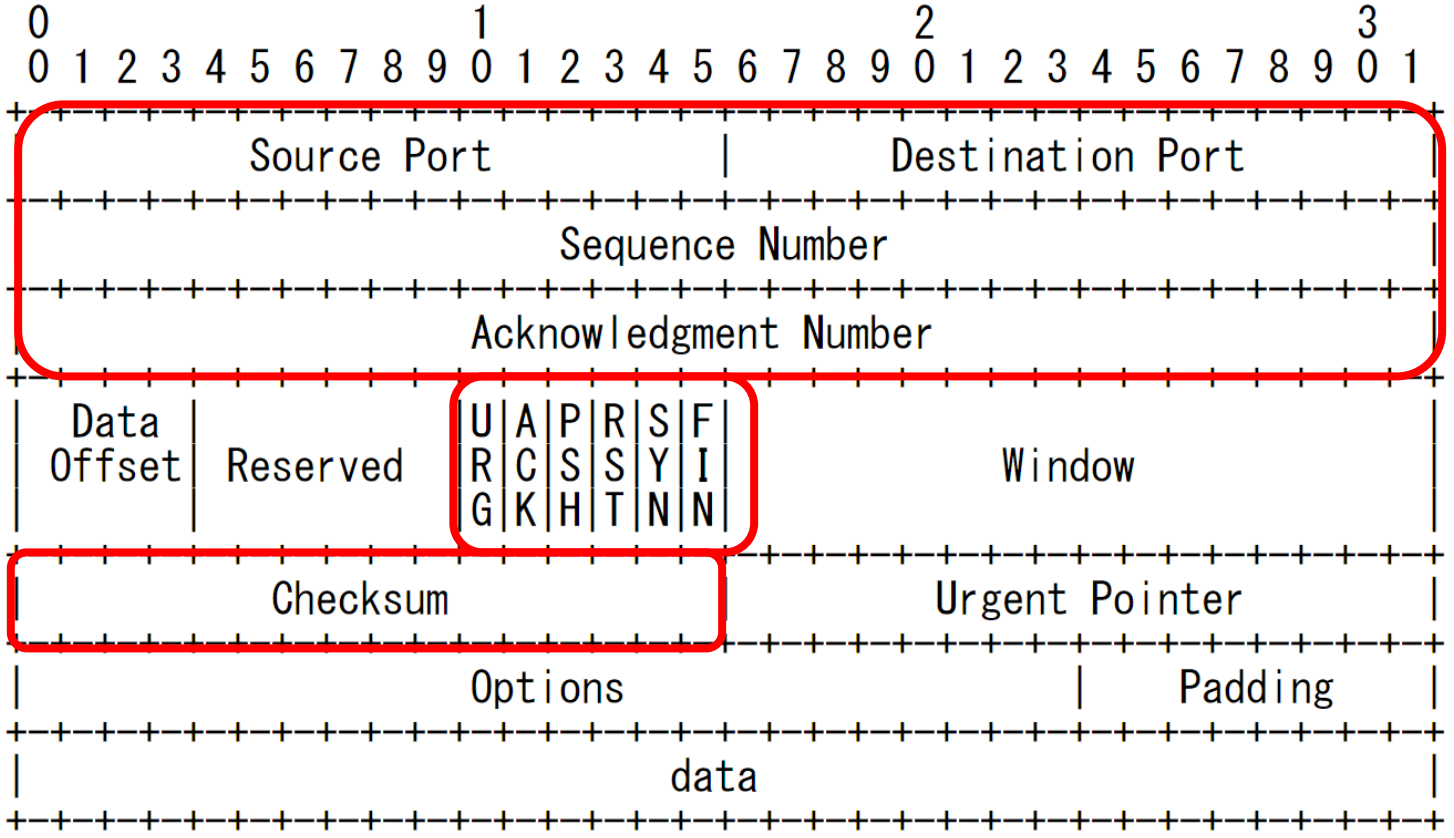
To Decept DNS Response: Easy and Simple(2/2)



References:
RFC768 User Datagram Protocol
RFC791 INTERNET PROTOCOL



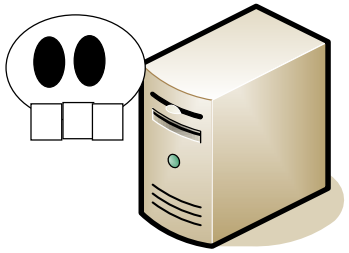
To Decept TCP Response: Easy and Simple



Reference: RFC793 TRANSMISSION CONTROL PROTOCOL

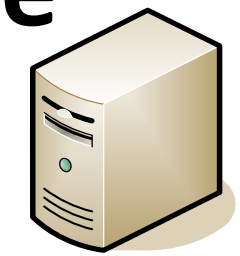
DQB architecture

evil.example.com
192.168.0.1

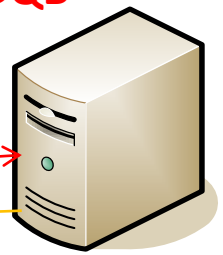


Malicious Host

DNS



DQB



evil.example.com
IN A 192.168.0.1

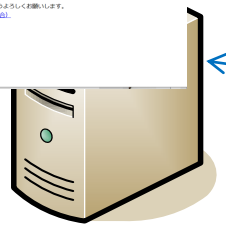
①

②

②’

172.16.0.1

Sorry page

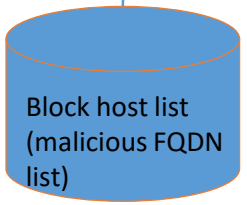


Landing Host(Safe Host)

evil.example.com
IN A 172.16.0.1

③’

client



①Client requests IP address of evil.example.com to DNS

②DNS responses IP address of evil.example.com to client（192.168.0.1）

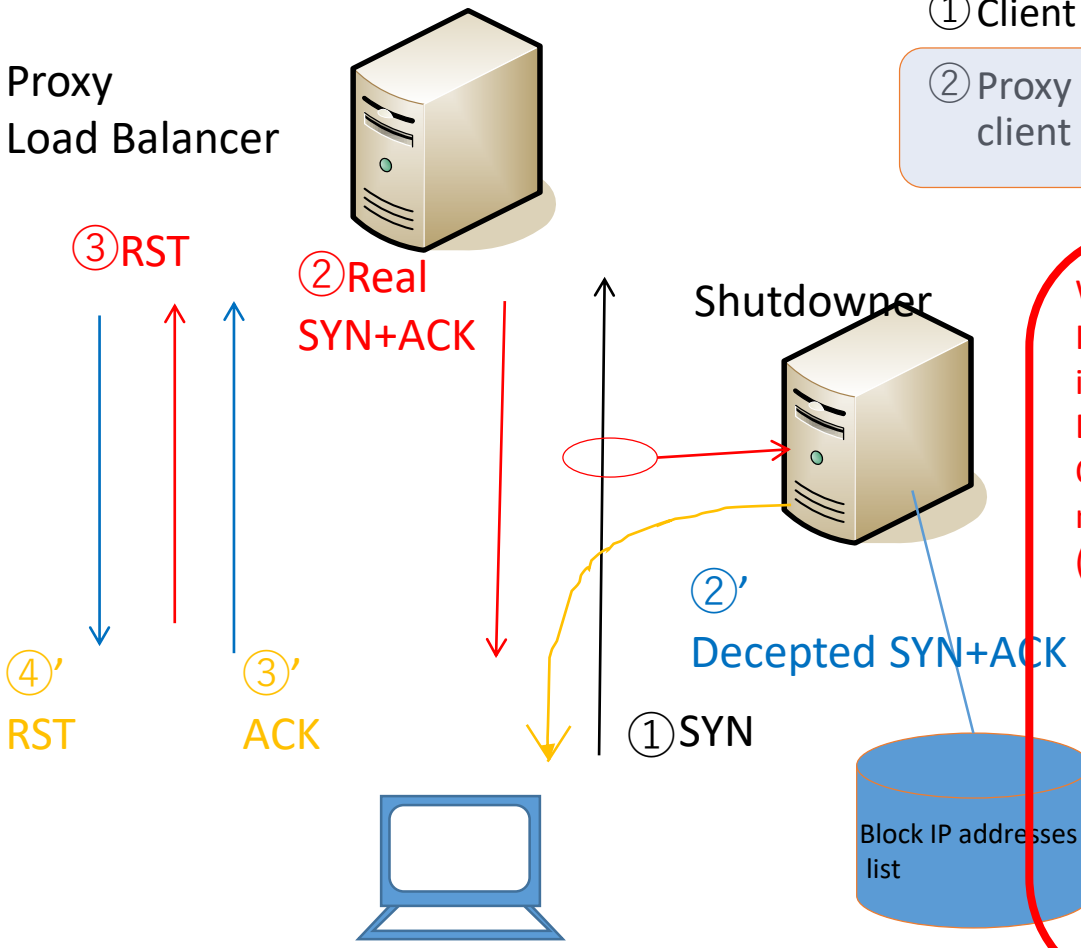
This is interesting

While monitoring request①,
If FQDN in request① exists in malicious FQDN list, response ②’ is sent to client
（172.16.0.1 is included in response②’）

Client receives response ②’, and client accesses to 172.16.0.1(③’)

…of course, response② is ignored

Shutdowner Architecture



①Client sends SYN packet to Proxy load balancer

②Proxy load balancer sends SYN+ACK packet to client

This is interesting

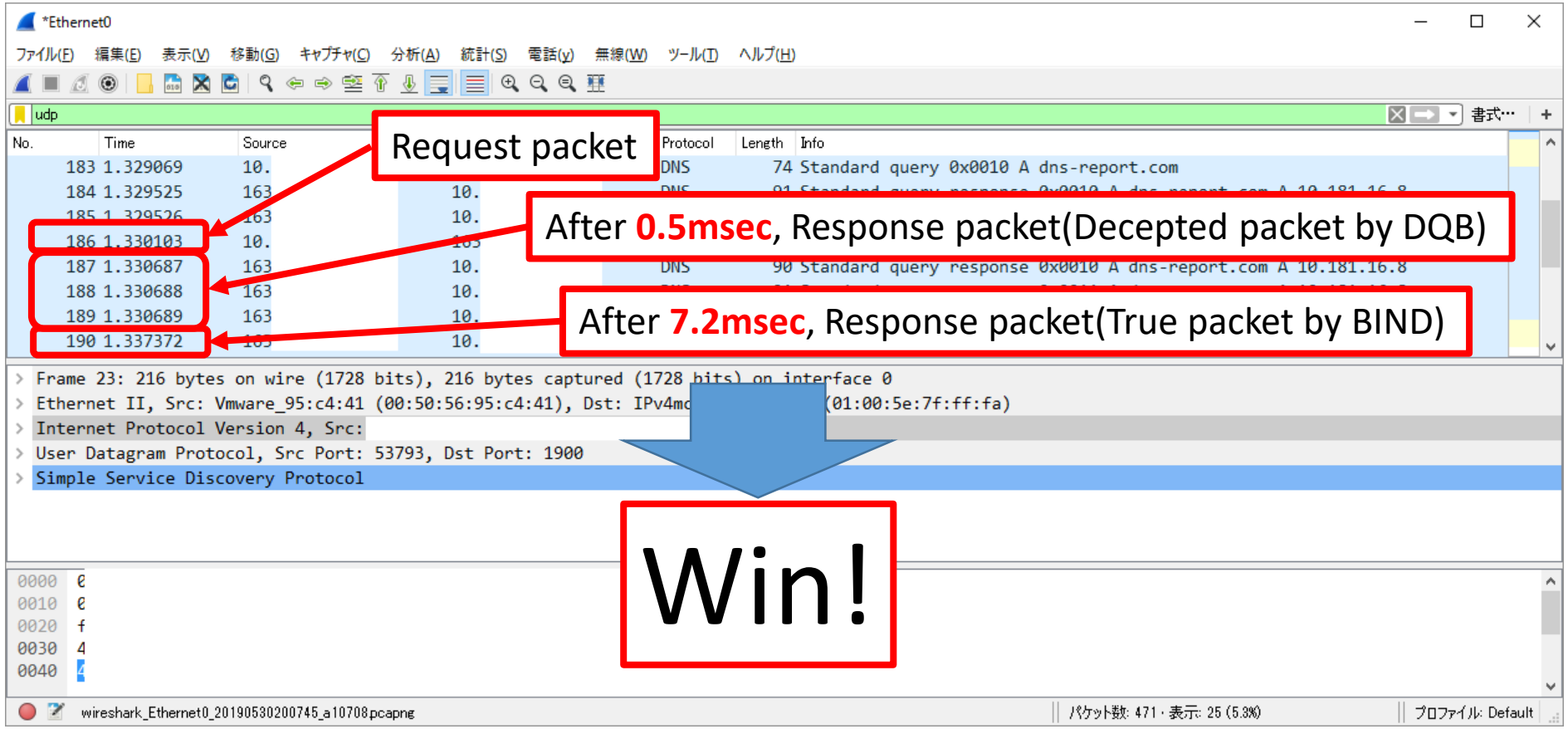
While SYN packet monitoring,
If SYN packet source IP address is included in Block IP addresses list,
Decepted SYN+ACK packet②' is sent.
Of course, sequence number in ②' is not related to sequence number in ② (Real SYN+ACK).

Client receives ②' packet and related ACK packet③'.
Proxy Load Balancer don't know the sequence number in ③', and sends RST packet④'.
When client receives ② after ②', client sends RST packet to Proxy Load Balancer because of receiving SYN+ACK②'.

Performance?

- 0.055～0.117(msec):DQB processing time from receiving packet to sending decepted response packet
  - Real DNS server software processes slower than DQB
- 0.019～0.023(msec): Shutdowner processing time from receiving SYN packet to sending decepted SYN+ACK packet
  - Real TCP/IP stack processes slower than Shutdowner

Performance in real environment



DQB and Shutdowner hardware spec?

- DQB works on:
  - PowerEdge R230(<$2k)
    - Xeon(R) CPU E3-1271 v3 @ 3.60GHz * 1
    - 16GB of memory
    - Intel I350 GbE NIC(4 ports)
- Shutdowner works on:
  - PowerEdge R230(<$2k)
    - Xeon(R) CPU E3-1271 v3 @ 3.60GHz * 1
    - 16GB of memory
    - Intel I350 GbE NIC(4 ports)

Simple Operation

Complex Systems Operations make works slower

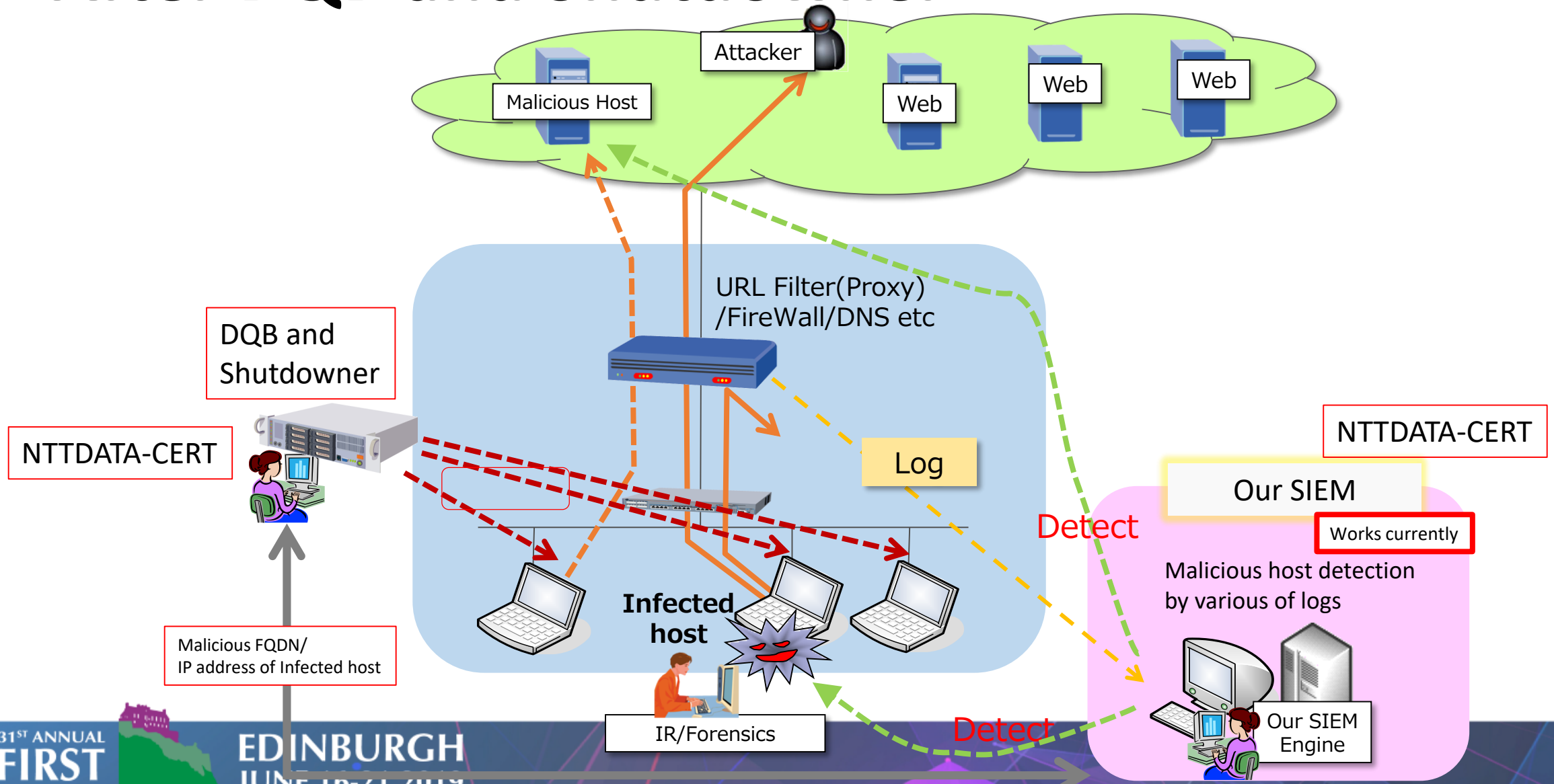
Web application for DQB/Shutdowner Operation

- We developed a Web application for managing DQB and Shutdowner
  - Add / View / Delete malicious FQDN or IP address simply
  - Malicious FQDN/IP address can be added by Web API in Web Application.

Released in 2015

- Almost no trouble for 4 years

After DQB and Shutdowner



After DQB and Shutdowner: Responding to malicious URL got faster

- Find suspicious URL by our SIEM or others
  - Consider whether URL is malicious or not(<1h)
  - Set malicious FQDN got from malicious URL to DQB(<1min)
  - Send request URL filter operators set of malicious FQDN once a week
  - After URL filter operators work, unset malicious FQDN from DQB
  - Done

- Even if malicious URLs are found oftenly, URL Filter operators don’t receive requests oftenly(once a week)
  - Set

Good point and Better point

- Good point (we thought before deployment)
  - Reducing access from our company to malicious hosts by using DQB
  - Reducing operations by simple Web UI
  - Reducing operations of URL filter operators

- Better point (we didn’t think before deployment)
  - No complaint from users
  - Presentation in Annual FIRST Conference
  - Malware infection detection(partly)

Our contact is shown in sorry page

Limitations and our environment's case

- Limitations
  - DQB cannot process **DNS request via TCP and DNS over TLS**
  - Decepted response by DQB is ignored **when DNSSEC is used**
  - **When IP address is included** in malicious URL(e.g. http://10.0.0.1/...), DQB don't work
- In our environment
  - **UDP is used for DNS request, and DNSSEC is disabled**, then DQB works well
  - **Not so much URL including malicious IP** address(es) found

No Problem!

Jackpot!

Decepting DNS response makes malware infected hosts accessing to “our” landing host

Example: Responding to Malware infection

- NTT DATA infected Ransomware in 5th, Jan. 2018…
  - Many nodes were crushed by Ransomware infection
- We use large amount of computers
  - above **20k～30k, Windows run most of computers**
  - Many of them:**Windows Embedded(without MS17-010 patches)**
- **Most of them goes to bluescreened**

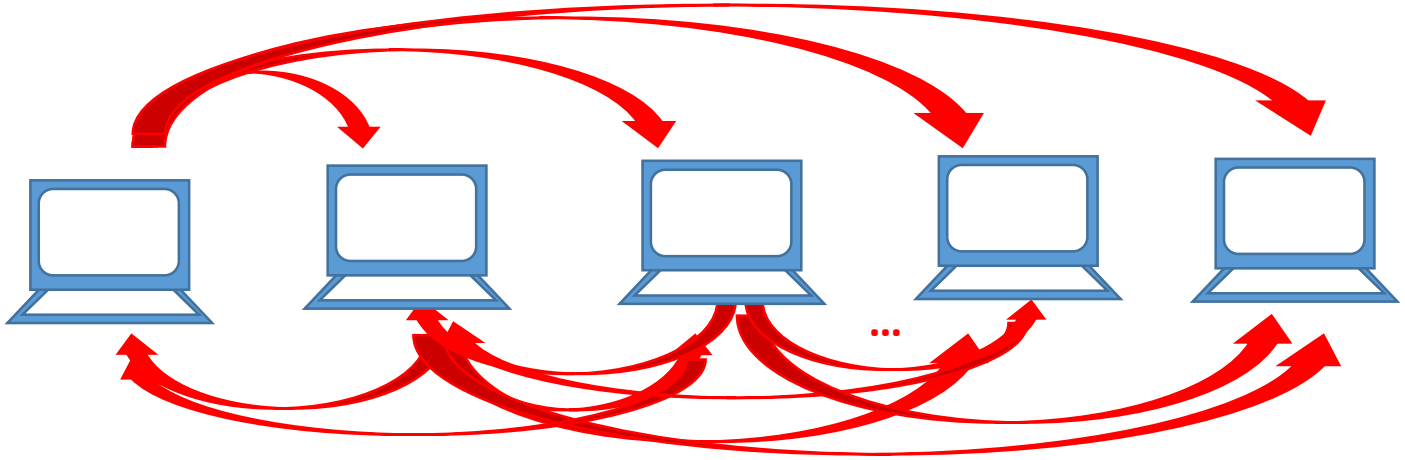
In NTT DATA's web site:

https://www.nttdata.com/jp/ja/news/information/2018/012201/

Increased access to DQB host

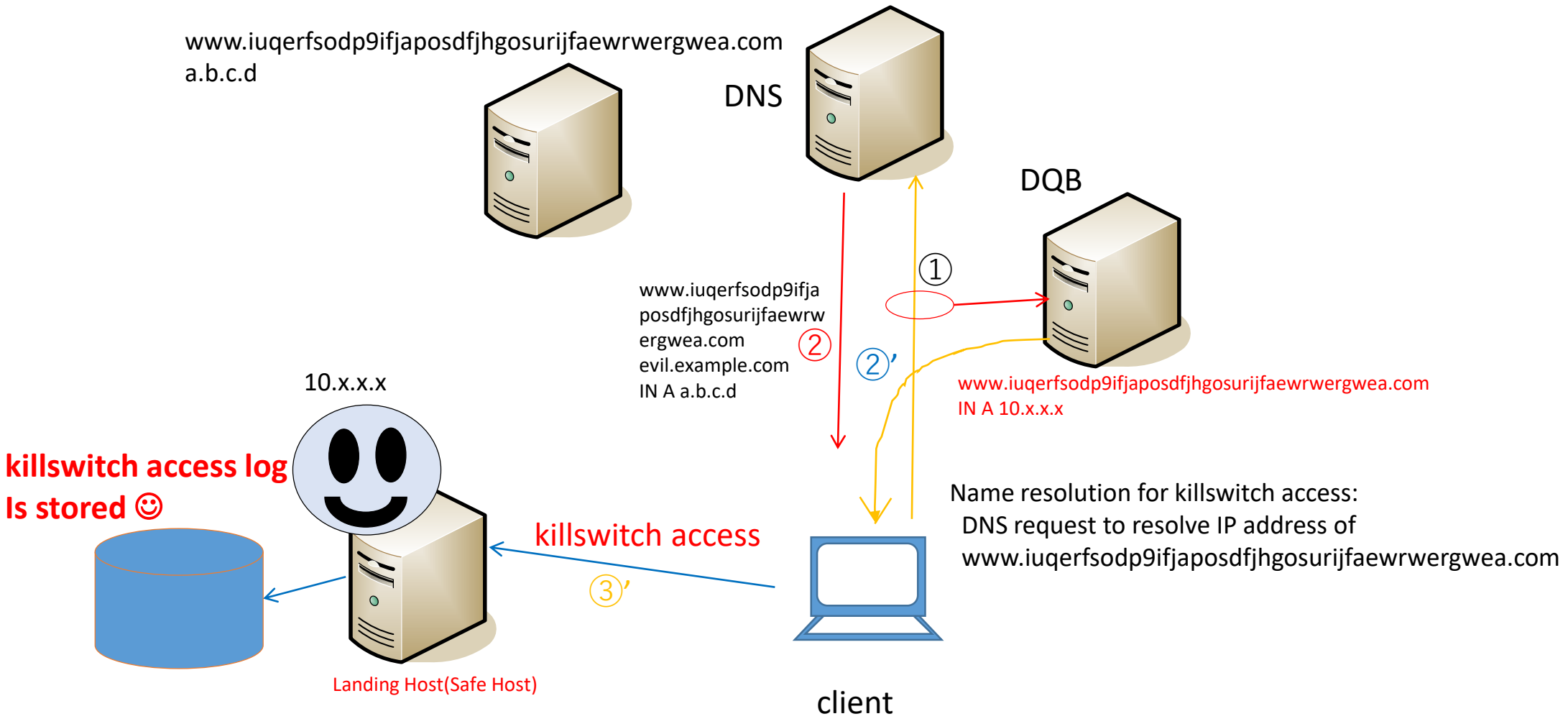
- When Ransomware runs on infected node
  - Attempts “Killswitch” FQDN resolution(by DNS)
  - DQB knows “Killswitch” FQDN and send decepted DNS response
  - DQB works hard, and access to host announced by DQB(we call “Landing Host”) increases

Why too many accesses were made by Ransomware?

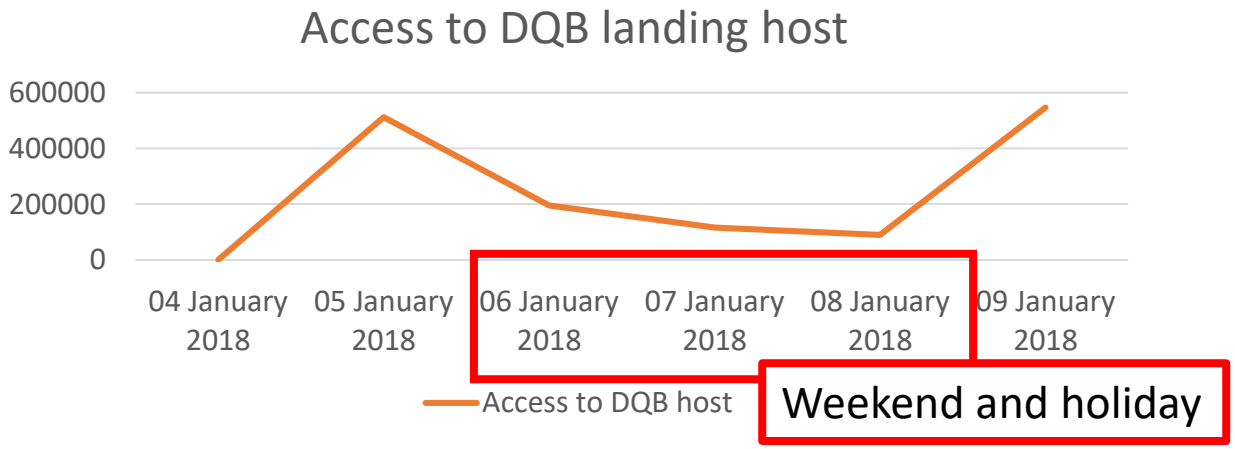


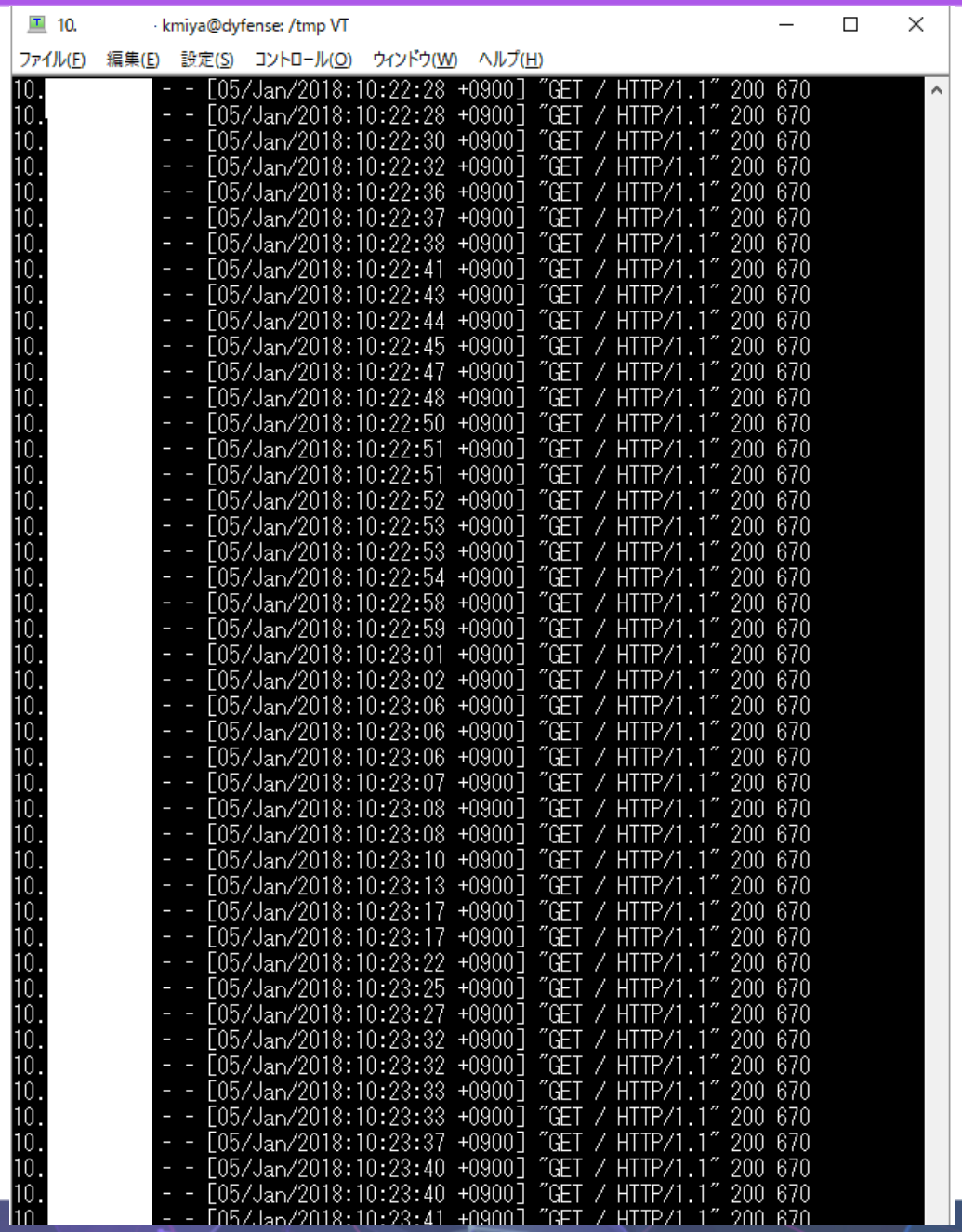
- After Infection, access to kill switch occurs
- Multiple Infections, **Multiple Accesses**

DQB work when ransomware is infected



Amount of Killswitch Access:





- About 500k accesses
  - 6 – 7 accesses to “landing host”

Responding to Ransomware infection

- Isolate network segment that includes infected hosts
- Harden terminal(s) to prevent infection
- Few terminals cannot be responded
  →use DQB log to exploit by using MS17-010(and place the target to bluescreened state)
  10.x.x.x - - [18/Jan/2018:02:31:39 +0900] "GET / HTTP/1.1" 200 670 "-" "-"
  www.iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea.com
  - We developed the auto response tool in a few hours and got effective operation tool (and **we got rest time**)
    - If we have PoC code for exploitation, crushing system is easier than getting shell access

Conclusion

- We don’t need so expensive solution(s), but we need(and developed) our requested tool
- Solution like “DQB” and “Shutdowner” can be developed if you understand network protocol and architecture basis and you can develop some tools by using C and Python ☺
- We may be able to develop tools not only detection, but also response by ourselves☺
- if you know your enemy and know yourself, in a hundred battles you will never be defeated; know your enemy (from “The Art of War” by Sun Tzu)

Any Question?

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References

This section is not talked but useful to understand DQB and Shutdowner architecture

For example: FQDN matching and frame building strategy

- Matching www.example.com
  www.example.com is described “¥3www¥7example¥3com¥0” in DNS request packet
  →DQB use FQDN “¥3www¥7example¥3com¥0”, and don’t parse “¥3www¥7example¥3com¥0” to “www.example.com”.
- Prebuilt DNS response except IP addresses, Port numbers and ID
  Don’t build packet fully and dynamically

Design for Performance

- Programming Language: C
- On-memory processing and intend CPU cache
  main loop: smaller, no library call (of course, systemcalls are not library call)
- Logging to shared memory(and write file by logger process)
- Don’t use malloc() timely, use malloc() for entire use at first.
  To prevent bugs caused by memory management mistaken
- Lock free(for delay prevention caused by scheduler)
  use flags instead of (any kind of) lock
- Read packet header +α only

Design for Performance

- Don’t use async processing for socket() to assure the time systemcall finished is the time decepted packet is sent

```
   int    asyn_flag = 0;
// (snip)
   fd = socket(PF_PACKET, SOCK_RAW, htons(ETH_P_ALL));
    (void)ioctl(fd, FIOASYNC, &asyn_flag);
```

- If you can, DPDK is suitable for DQB and Shutdowner
- Shutdowner: use bloom filter, use pointer array(use syntax like “if” or switch … case in IP address matching)
  void *func[IP address space];
  func[] is valiable that contains function to send decepted syn+ack packet or do nothing when packet is received, call func[srcIP]
- DQB: Don’t process dynamically like FQDN parse, and preprocess to build response packet framework

Traffic Generator by using Linux pktgen

```
#!/bin/sh

modprobe pktgen

echo "rem_device_all"          > /proc/net/pktgen/kpktgend_0
echo "add_device eth2"          > /proc/net/pktgen/kpktgend_0
echo "count 100000"             > /proc/net/pktgen/eth2
echo "clone_skb 1"              > /proc/net/pktgen/eth2
echo "pkt_size 60"              > /proc/net/pktgen/eth2
# delay specified value (nanosec order)
echo "delay 20000"              > /proc/net/pktgen/eth2
echo "src_min 172.16.0.2"       > /proc/net/pktgen/eth2
echo "src_max 172.16.0.2"       > /proc/net/pktgen/eth2
echo "src_mac a0:36:9f:a8:8a:3c" > /proc/net/pktgen/eth2
echo "dst 172.16.0.3"           > /proc/net/pktgen/eth2
echo "dst_mac a0:36:9f:a8:86:b8" > /proc/net/pktgen/eth2
echo "start"                    > /proc/net/pktgen/pgctrl

cat /proc/net/pktgen/eth2
```