# BIND 9

## (Part 2 - Long-Term Statistics Monitoring and Log Analysis)

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# Welcome

Welcome to part two of our BIND 9 webinar series

# In this Webinar

- Identifying outliers in BIND 9 logfiles
- BIND 9 monitoring from the `named.stats` file
- BIND 9 monitoring with the statistics channel
- Using open source tools to store and display metrics
- Using open source tools to search and analyze logs
- BIND 9 logs and remote syslog best practice
- Best practices for metrics to monitor for authoritative and recursive

# Goals of monitoring

- finding outliers / anomalies -> potential security or performance problem
- observe change in traffic patterns
- observe change in load (CPU load, traffic load etc)
- observe change in protocol use (new resource records, IPv4 vs. IPv6 usage, UDP vs. TCP usage, DoH/DoT usage)

# Identifying outliers in BIND 9 logfiles

# Outliers

- outliers in log-files are entries that do not appear during *normal* operation
- one approach to catch outliers is called *Artificial Ignorance*
  - it is not the only approach
  - works best for small to medium size installations
  - first described by Security researcher Marcus J. Ranum ("artificial ignorance: how-to guide" https://www.ranum.com/security/computer_security/papers/ai/)

# Artificial Ignorance

- the concept of AI (Artificial Ignorance)
  - there are two types of log messages
    - the ones the admin does not care about and do not need attention
    - the ones the admin does care about and need attention

# Artificial Ignorance - Messages that do not need attention

- the log messages that the admin does not care about and do not need attention are *noise*
  - it might be still valid to collect these messages in the logs, for example for statistical analysis
  - so the AI system will filter them (suppress them)
  - what are left are, by definition, the messages that **do** need attention

# Artificial Ignorance - Messages that do need attention

- the messages that are passing the filter fall in two categories
  - new messages that are not indicating a security or performance issue
    - a new filter (usually a regular expression) needs to be added to the software to hide this type of message in the next run
  - new messages that do indicate a potential security or performance issue
    - the admin needs to investigate the root case of the messages and need to fix the cause for the log messages

# Artificial Ignorance - operation

- the AI software is run periodically (every 24 hours, every hour), the results are send via mail (chat etc) to the group of administrators
  - in the ideal case, the mail message will have no new log messages
    - the mail (chat etc) should be send even if no new information is available
  - in case a log message appears, it must be dealt with until the next run of the software (internal SLA)

# Artificial Ignorance - Software

- there are several implementations of "Artificial Ignorance" available
  - log templater (TMPLTR): http://www.uberadmin.com/Projects/logtemplater/index.html
  - NBS (never before seen): https://www.ranum.com/security/computer_security/code/
  - Log message classification with syslog-ng https://lwn.net/Articles/369075/

# Artificial Ignorance - additional information

- System Logging and Log Analysis (Marcus J. Ranum): https://www.ranum.com/security/computer_security/archives/logging-notes.pdf
- Syslog normalization https://rainer.gerhards.net/2010/02/syslog-normalization.html
- Building a 100K log/sec system (David Lang / Intuit) http://talks.lang.hm/talks/topics/Logging/LISA_2012/logging_paper_slides.pdf

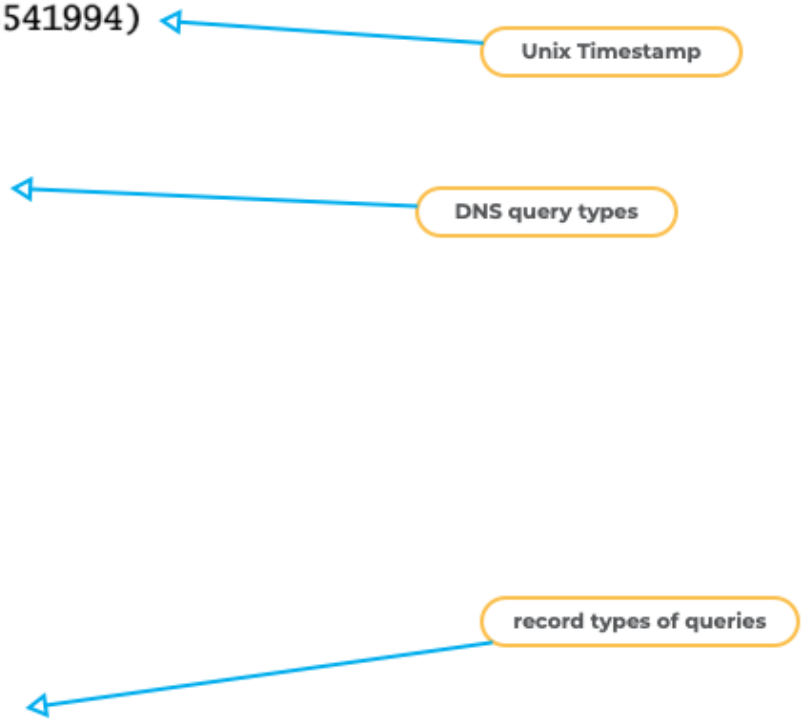
# BIND 9 monitoring from the "named.stats" file

# BIND 9 "named.stats"

- the command `rndc stats` will trigger a BIND 9 server to write a file with internal statistics
  - the statistics content is written to the file `named.stats` in the BIND 9 servers home directory
  - the directory and the name of the file can be changed in the BIND 9 configuration file `named.conf` with the `statistics-file` directive

# BIND 9 "named.stats" example (1)

```
+++ Statistics Dump +++ (1615541994)
++ Incoming Requests ++
             4730864 QUERY
                   2 IQUERY
                   4 STATUS
               13676 NOTIFY
               26703 UPDATE
++ Incoming Queries ++
                1343 Others
             3076998 A
               66130 NS
                4654 CNAME
               64919 SOA
                 818 PTR
                   7 HINFO
              127183 MX
              182782 TXT
                 248 AFSDB
              687710 AAAA
                  28 EID
                4552 SRV
                  85 NAPTR
                 194 A6
               50210 DS
                  15 SSHFP
```

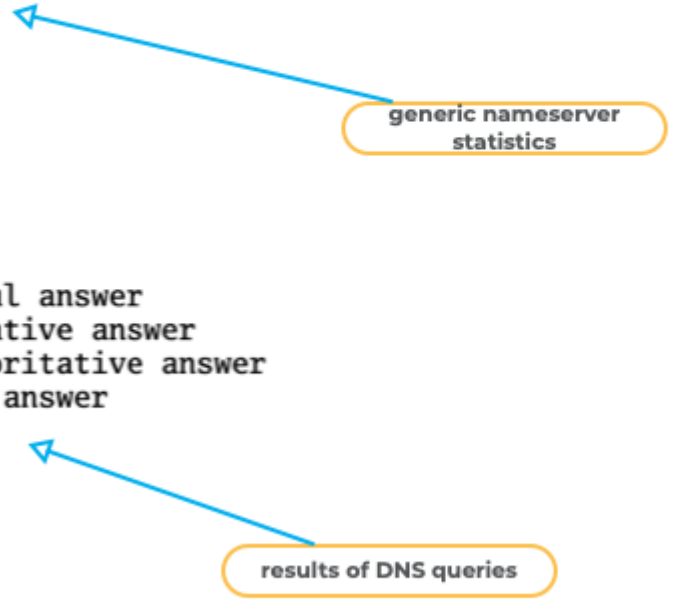


# BIND 9 "named.stats" example (2)

```
++ Outgoing Rcodes ++
             4527679 NOERROR
                 150 FORMERR
              108122 SERVFAIL
              114402 NXDOMAIN
                   6 NOTIMP
               18177 REFUSED
                   1 NOTZONE
                   2 BADVERS
++ Outgoing Queries ++
[View: default]
                3826 A
                  44 NULL
                  33 TXT
                3718 AAAA
                 386 DS
                 385 DNSKEY
```


# BIND 9 "named.stats" example (3)

```
[View: _bind]
++ Name Server Statistics ++
             3709796 IPv4 requests received
             1061603 IPv6 requests received
             4393780 requests with EDNS(0) received
                   2 requests with unsupported EDNS version received
               53390 requests with TSIG received
              164344 TCP requests received
                  19 TCP connection high-water
                 241 auth queries rejected
               17550 recursive queries rejected
                   2 transfer requests rejected
             4768539 responses sent
               94633 truncated responses sent
             4391938 responses with EDNS(0) sent
               53390 responses with TSIG sent
             4185600 queries resulted in successful answer
             4557536 queries resulted in authoritative answer
               45207 queries resulted in non authoritative answer
               44148 queries resulted in referral answer
              258593 queries resulted in nxrrset
              108125 queries resulted in SERVFAIL
              114402 queries resulted in NXDOMAIN
                 478 queries caused recursion
                1842 queries dropped
               17599 other query failures
                1018 requested transfers completed
               26702 updates completed
                   1 updates failed
```

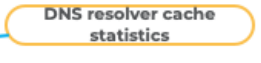


# BIND 9 "named.stats" example (4)

```
++ Resolver Statistics ++
[Common]
[View: default]
                  573 IPv4 queries sent
                 7819 IPv6 queries sent
                  481 IPv4 responses received
                 7527 IPv6 responses received
                   75 NXDOMAIN received
                 1611 truncated responses received
                 2284 query retries
                  384 query timeouts
                 1631 IPv4 NS address fetches
                 1763 IPv6 NS address fetches
                    1 IPv4 NS address fetch failed
                  226 IPv6 NS address fetch failed
                 1087 DNSSEC validation attempted
                  560 DNSSEC validation succeeded
                  527 DNSSEC NX validation succeeded
                 3043 queries with RTT < 10ms
                 4418 queries with RTT 10-100ms
                  523 queries with RTT 100-500ms
                   19 queries with RTT 500-800ms
                    5 queries with RTT > 1600ms
                   32 bucket size
                 8017 COOKIE send with client cookie only
                  292 COOKIE sent with client and server cookie
                  692 COOKIE replies received
                  692 COOKIE client ok
                   11 bad cookie rcode
```


# BIND 9 "named.stats" example (5)

```
++ Cache Statistics ++
[View: default]
               21326 cache hits
               14054 cache misses
                 782 cache hits (from query)
                 549 cache misses (from query)
                   0 cache records deleted due to memory exhaustion
                2918 cache records deleted due to TTL expiration
                 288 cache database nodes
              262144 cache database hash buckets
             1596979 cache tree memory total
             1183953 cache tree memory in use
             1188009 cache tree highest memory in use
              651264 cache heap memory total
              392616 cache heap memory in use
              392616 cache heap highest memory in use
```



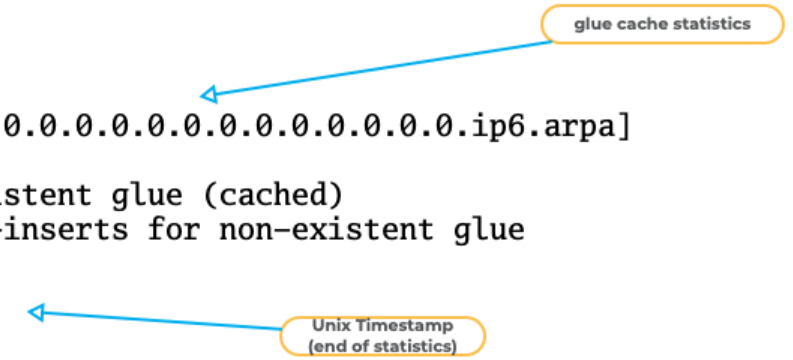

# BIND 9 "named.stats" example (6)

```
[example.net]
              124186 queries resulted in successful answer
              162169 queries resulted in authoritative answer
               20111 queries resulted in nxrrset
               17872 queries resulted in NXDOMAIN
                  83 requested transfers completed
                   4 updates completed
              148826 UDP queries received
               13343 TCP queries received
```

# BIND 9 "named.stats" example (7)

```
++ Per Zone Glue Cache Statistics ++
[.]
[localhost]
[127.in-addr.arpa]
[0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.ip6.arpa]
[example.org]
                179 Hits for non-existent glue (cached)
                139 Miss-plus-cache-inserts for non-existent glue

--- Statistics Dump --- (1615541994)
```



# Zone-Statistics

- Zone statistics need to be enabled in the BIND 9 configuration file `named.conf`
  - the statement `zone-statistics yes;` inside the `options` block enables the zone statistics for all zones

```
options {
   [...]
   zone-statistics yes;
};
```

# Zone-Statistics

- It is also possible to enable the zone statistics only for selected zones
  - This is done with the statement `zone-statistics yes;` inside the `zone` block:

```
zone "example.org" in {
     type primary;
     file "primary/example.org";
     zone-statistics yes;
};
```

# Monitoring with "named.stats"

- many popular monitoring tools offer modules to use the data in the `named.stats` file
  - LibreNMS https://www.librenms.org/
  - Nagios https://www.nagios.org/
  - Icinga https://icinga.com/
  - Prometeus https://prometheus.io/
  - NetData https://www.netdata.cloud/
  - many more

# Challenges with "named.stats"

- BIND 9 will always append new statistics to the `named.stats` file, the file will always grow
  - the file should be purged from time to time, as monitoring plugins usually read the file from the beginning to find the latest information
- the `named.stats` file contains human readable data, which needs to be parsed by a tool
  - the contents of `named.stats` can change with new BIND 9 releases, the monitoring plugins might fail when the parser is not well written.

BIND 9

# BIND 9 monitoring with the statistics channel

# BIND 9 http statistics channel

- The BIND 9 statistics can also be retrieved from a running BIND 9 server via the http protocol
  - BIND 9 has a tiny build-in web-server
  - It provides the statistics data in XML or JSON format

# BIND 9 statistics channel vs. "named.stats"

- The BIND 9 statistics channel has some benefits compared to the older `named.stats` statistics
  - The statistics can be read over the network
  - The statistics comes in structured data (XML or JSON) that is parse-able by software (more robust monitoring)
  - The format of the statistics data is versioned
    - A change in the statistics format will not break existing tools

# BIND 9 statistics channel dependencies

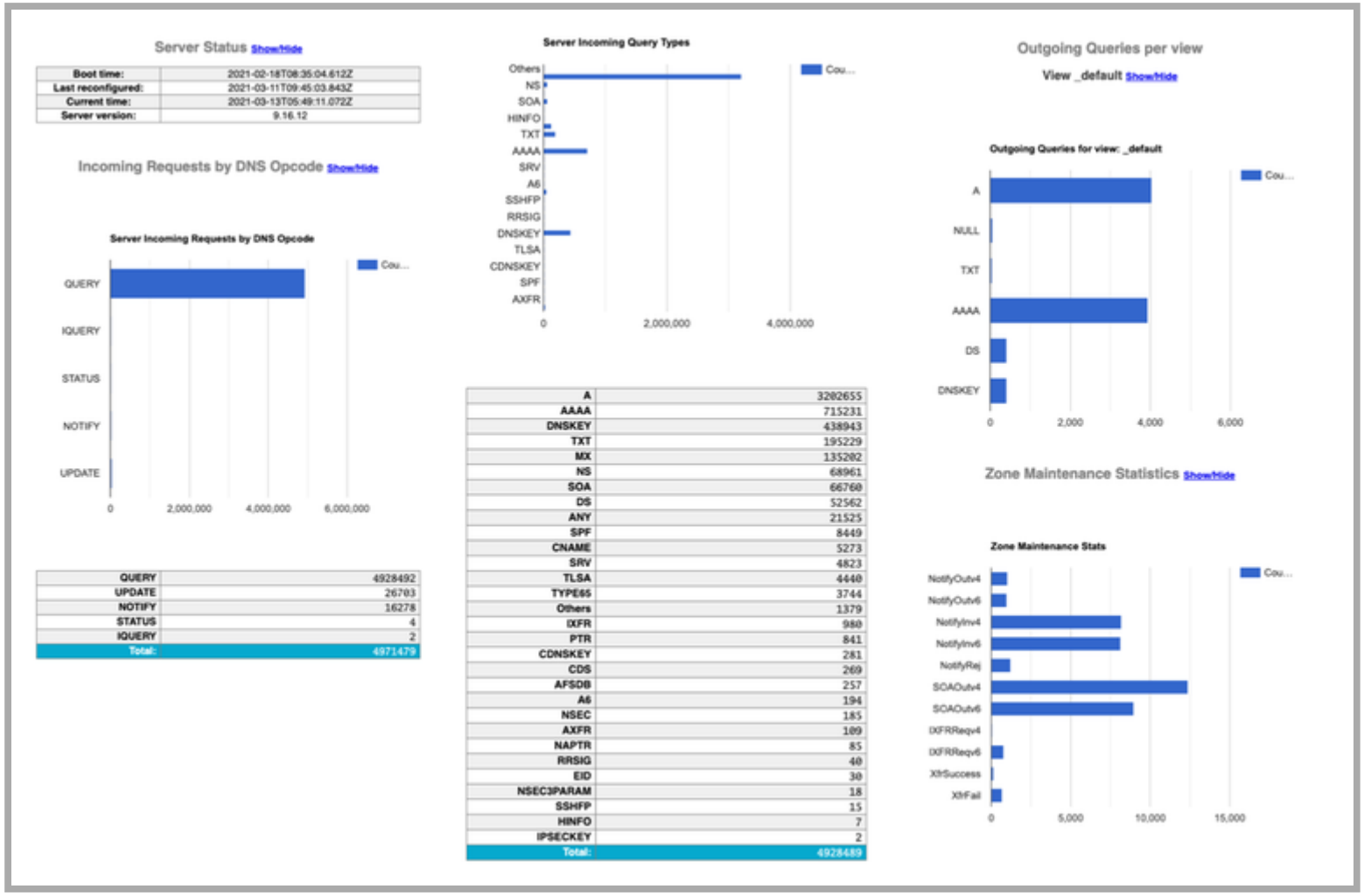
- In order to provide the statistics data over XML, BIND 9 must be compiled with *libxml2* support
- For JSON output, the BIND 9 server needs to be compile with support for *json-c* (https://github.com/json-c/json-c/wiki)
- The ISC BIND 9 packages contain the XML and JSON functions: https://kb.isc.org/docs/isc-packages-for-bind-9

# BIND 9 statistics channel configuration

- The BIND 9 statistics channel is enabled in the BIND 9 configuration file `named.conf`
  - Zone statistics can be enabled with the same statements used for the `named.stats` statistics
  - It has its own configuration block

```
statistics-channels {
     inet 192.0.2.53 port 8053 allow { localhost; adminnets; };
     inet fd00::1053 port 8053 allow { fd00::/64; };
};
```

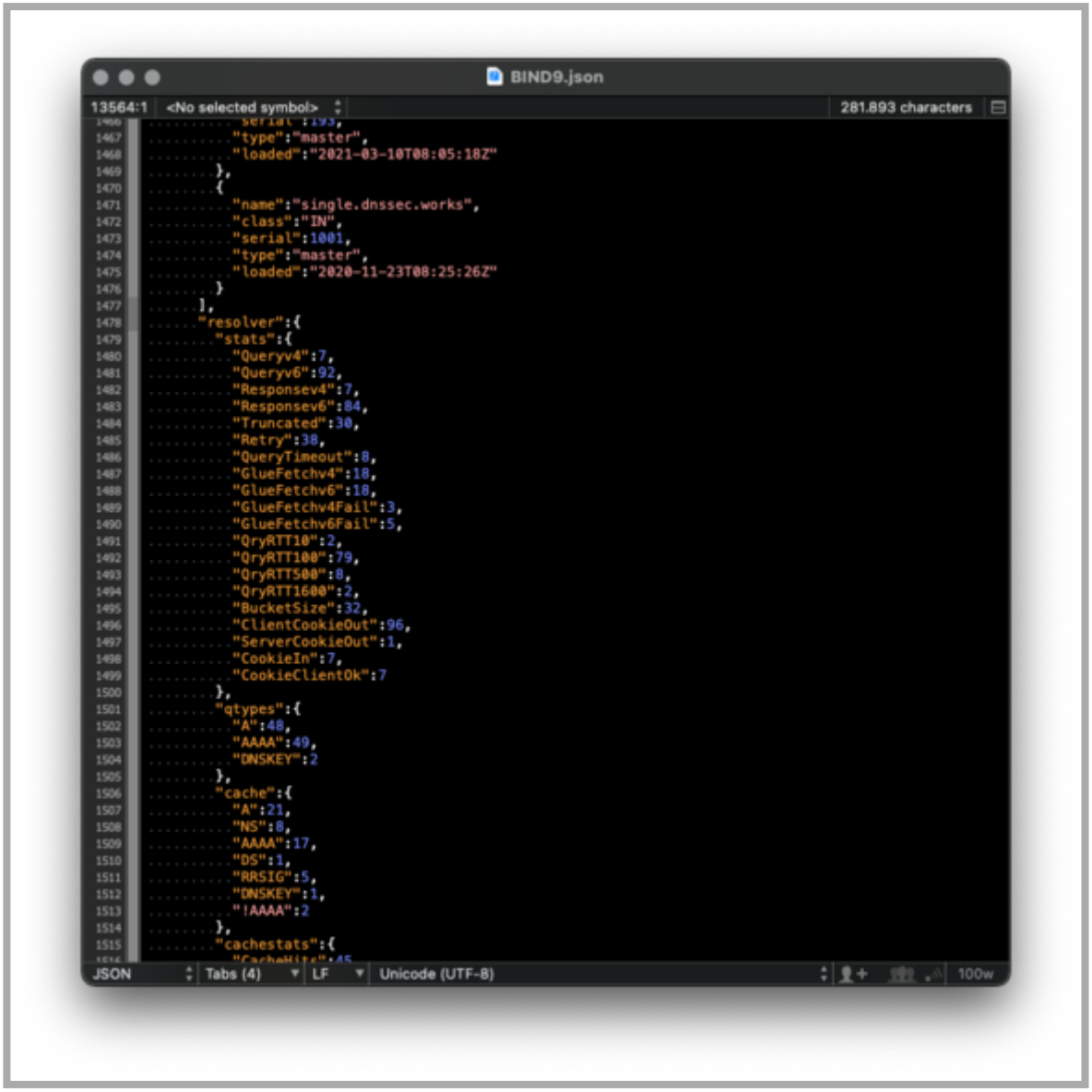
# BIND 9 statistics channel



# JSON Statistics

- JSON (JavaScript Object Notation) is an open standard file format that uses human-readable text
  - JSON is faster to parse than XML
  - Some (many?) people find JSON easier to work with compared to XML

# BIND 9 statistics channel



# Security recommendations for the statistics channel

- The BIND 9 statistics channel should not be exposed to the open Internet without authentication
  - It reveals internal information that can be use to attack the DNS server
  - It increases the attack surface
- Best practices
  - Bind the statistics channel only to internal management networks
  - Protect the BIND 9 statistics channel with a reverse web proxy (NGINX, Caddy, OpenBSD httpd etc) with basic authentication or TLS client certificate authentication

# Additional information on the statistics channel

- Operating statistics provided by BIND statistics channels https://kb.isc.org/docs/aa-01123
- Using BIND's XML statistics-channels https://kb.isc.org/docs/aa-00769

BIND 9

# Using open source tools to store and display metrics

# Prometheus

- Prometheus is a popular monitoring solution
  - Open source: Apache 2 license
  - Homepage: https://prometheus.io/
- Prometheus is easy to deploy and scales from small to large networks

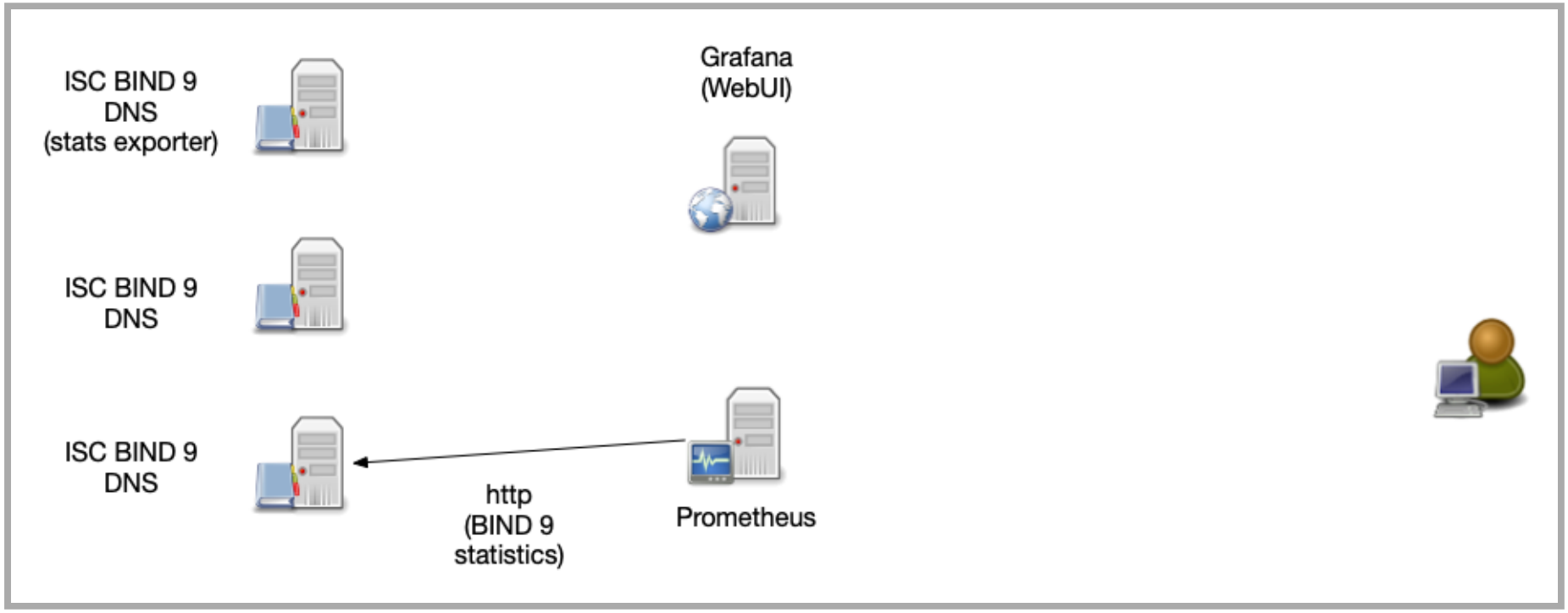
# Prometheus architecture

- small agent programs (called "exporters") collect data
  - exporters offer the data over http in a key/value format
  - easy to test the correct function of an agent with a web-browser of http command line tool (such as `curl`)
  - it is easy to write custom exporters
  - exporter agent can collect data local on the BIND 9 server (`named.stats`) or via network (statistics channel)

# Prometheus architecture

- Central Prometheus server collects the data from all agents and stored the data into a time series database
- Data can be queried over a web interface
- Visualization via Prometheus Expression Browser (simple) or Grafana (elaborate)

# Prometheus architecture



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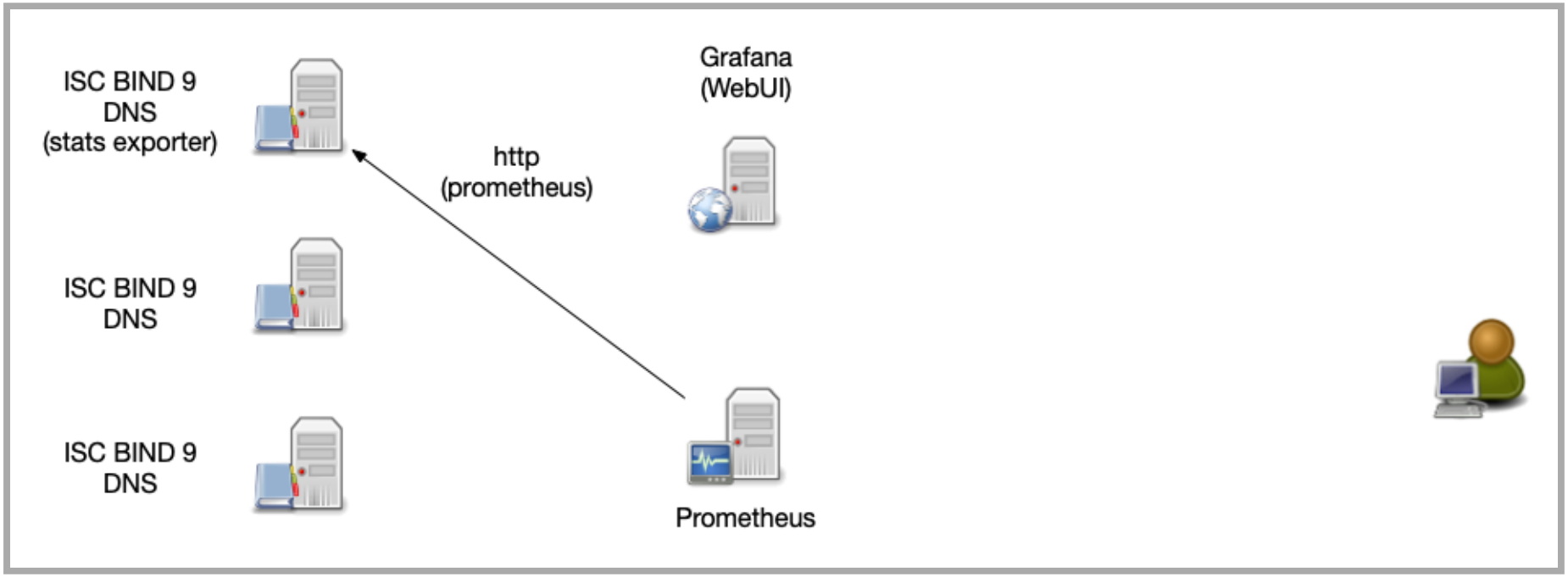

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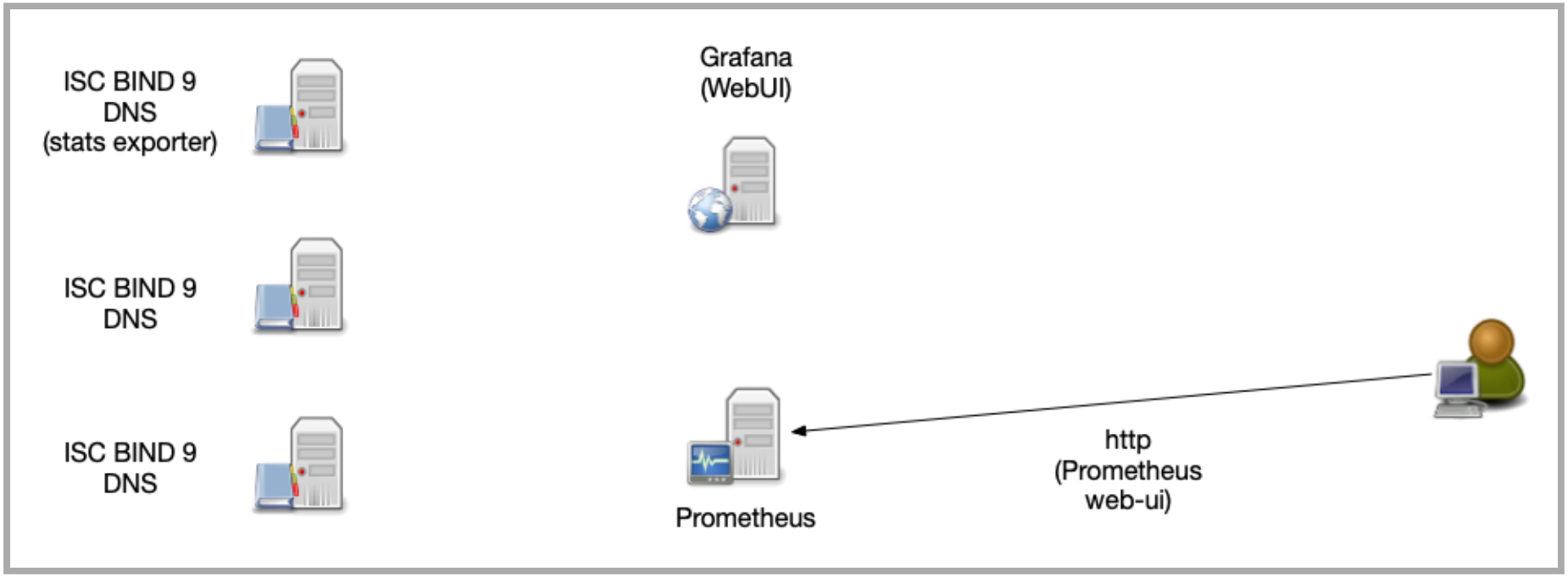

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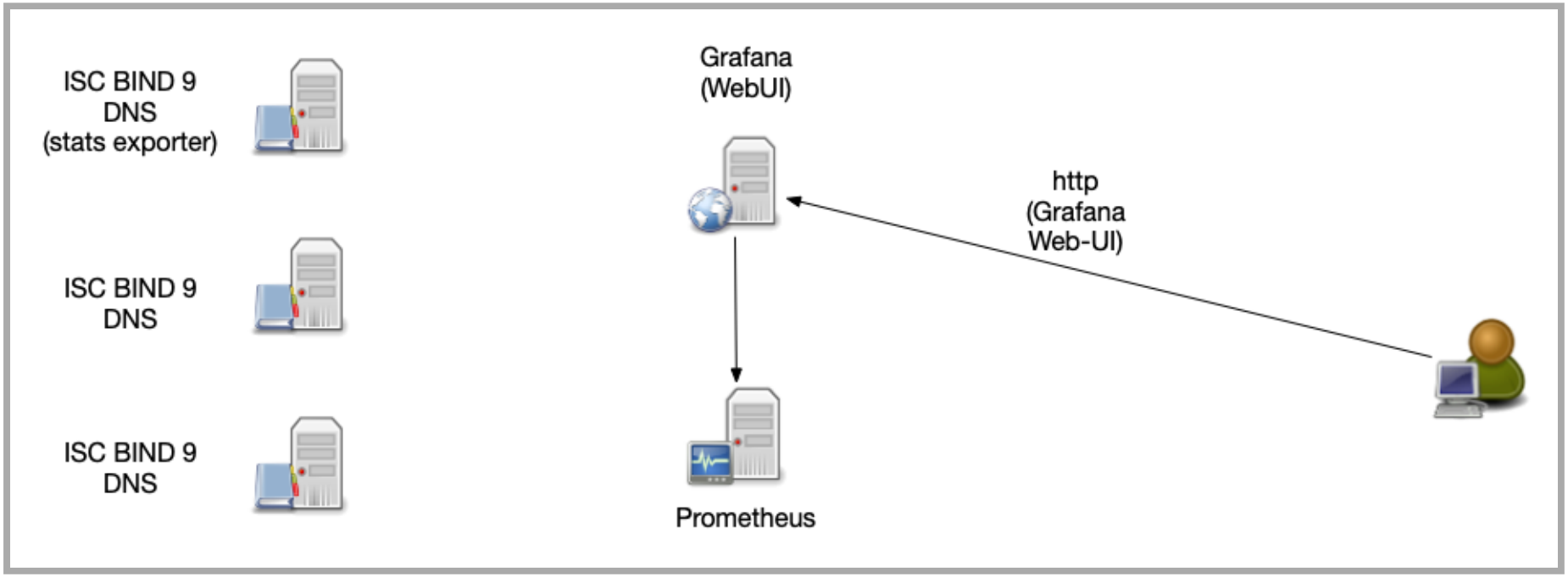


# Prometheus exporter for DNS

- BIND 9 stats exporter (`named.stats`): https://github.com/qiangmzsx/bind_stats_exporter
- BIND 9 statistics exporter from ISC (as part of Stork) https://cloudsmith.io/~isc/repos/stork/groups/
- BIND 9 statistics exporter (statistics channel): https://github.com/prometheus-community/bind_exporter
- DNS latency monitor exporter: https://github.com/openshift/managed-prometheus-exporter-dns
- DNSSEC signature validity and expiration monitor exporter: https://github.com/chrj/prometheus-dnssec-exporter
- DNS Record TTL monitor exporter: https://github.com/bencord0/dnsrecordttl_exporter
- Node DNS exporter (monitors the DNS configuration on a DNS client/cloud instance): https://github.com/evry-ace/node-dns-exporter
- DNS Lookup test exporter: https://github.com/kobtea/dns_lookup_exporter

BIND 9

# Using open source tools to search and analyze logs

# The ELK Stack

- ELK is a popular solution for an centralized log management. ELK combines the open source tools
  - Elastic Search https://www.elastic.co/elasticsearch/
  - Logstash https://www.elastic.co/logstash
  - Kibana https://www.elastic.co/kibana
    - Kibana can be replaced with Grafana https://grafana.com/docs/grafana/latest/datasources/elasticsearch/

# Logstash

- Logstash collects log data from various sources and formats
- Logstash can normalize and filter the data
- After transformation, Logstash stores the data in a central database (usually into Elastic-Search)
  - other outputs are possible, like Syslog, file, MongoDB, StatsD, Network-Monitoring …)

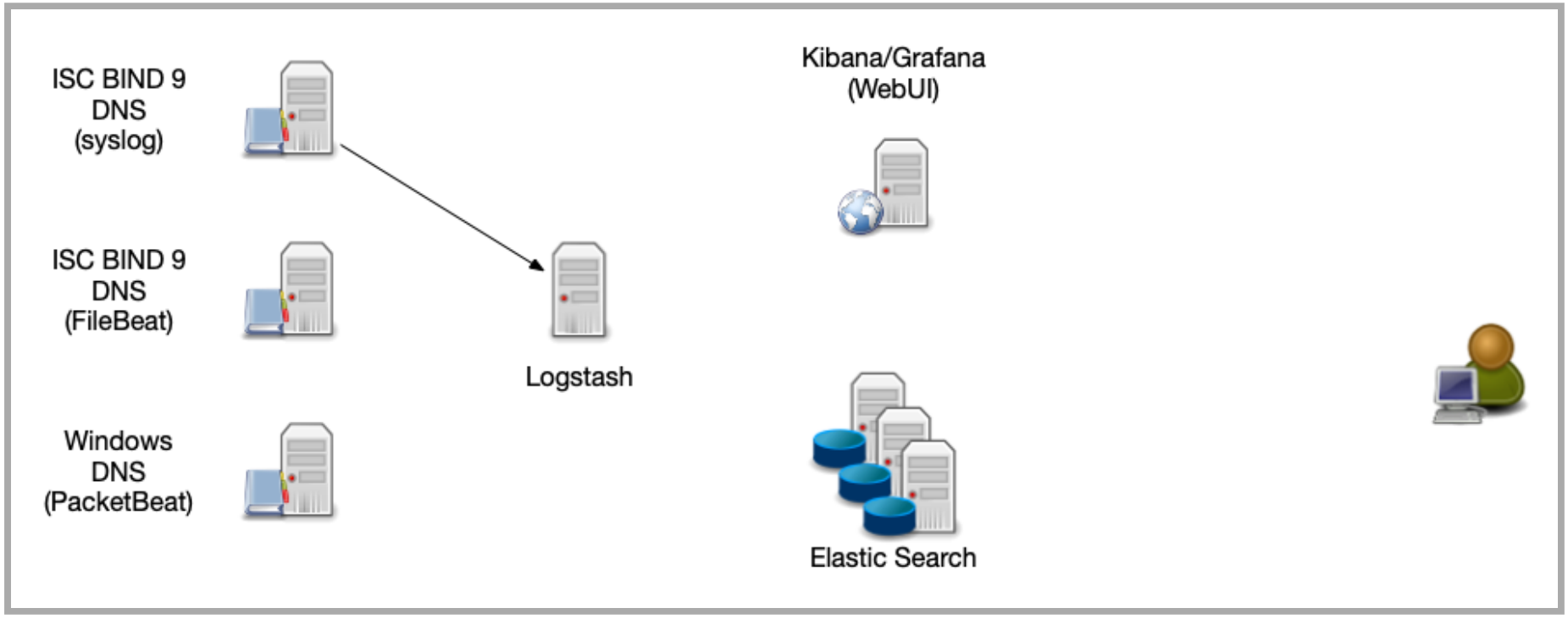
# Elastic-Search

- Elastic-Search is a distributed search and analysis engine
- Elastic-Search can work with large amounts of data
- Elastic-Search provides log-analysis, monitoring, anomaly-detection and SIEM capabilities (Security information and event management)

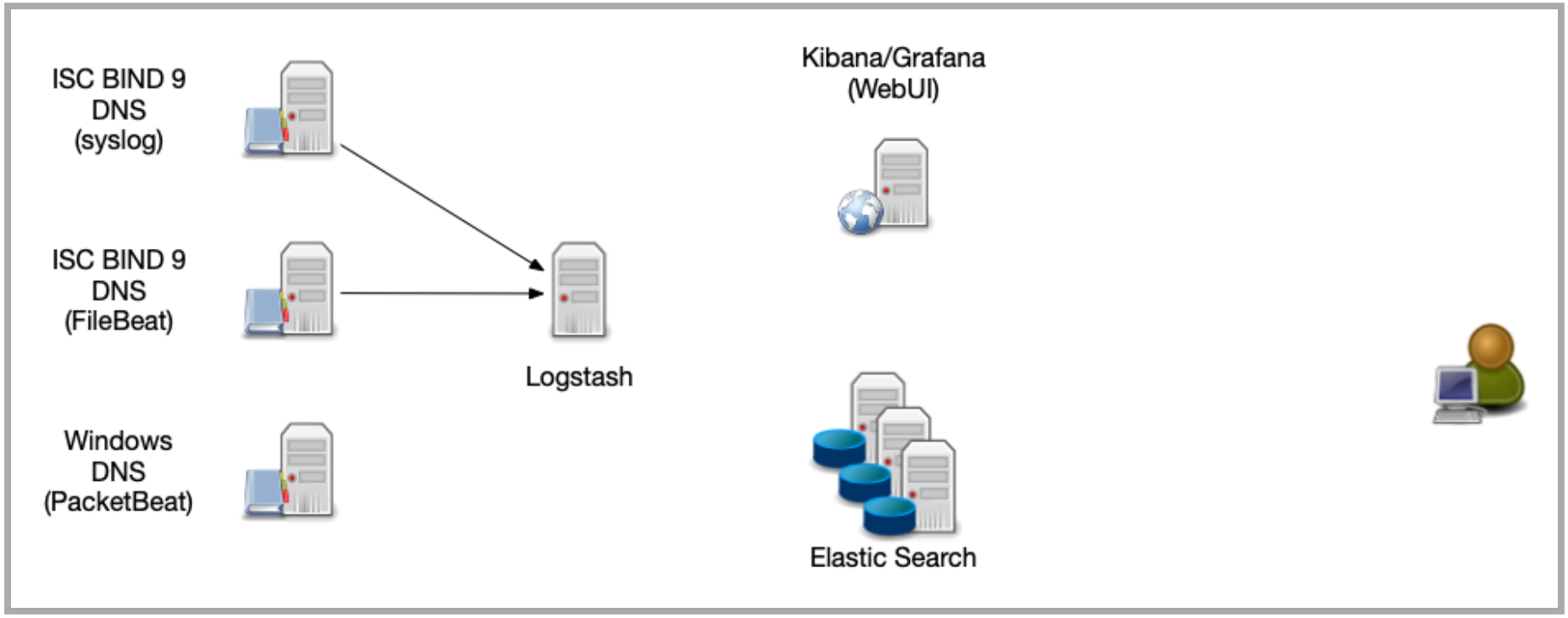
# Kibana / Grafana

- Kibana / Grafana visualize the data stored in Elastic Search
- Query the log-data
- Interactive "drill down" into the dataset
- Graphical trend analysis
- Uptime monitoring

# ELK Stack Architecture



# ELK Stack Architecture



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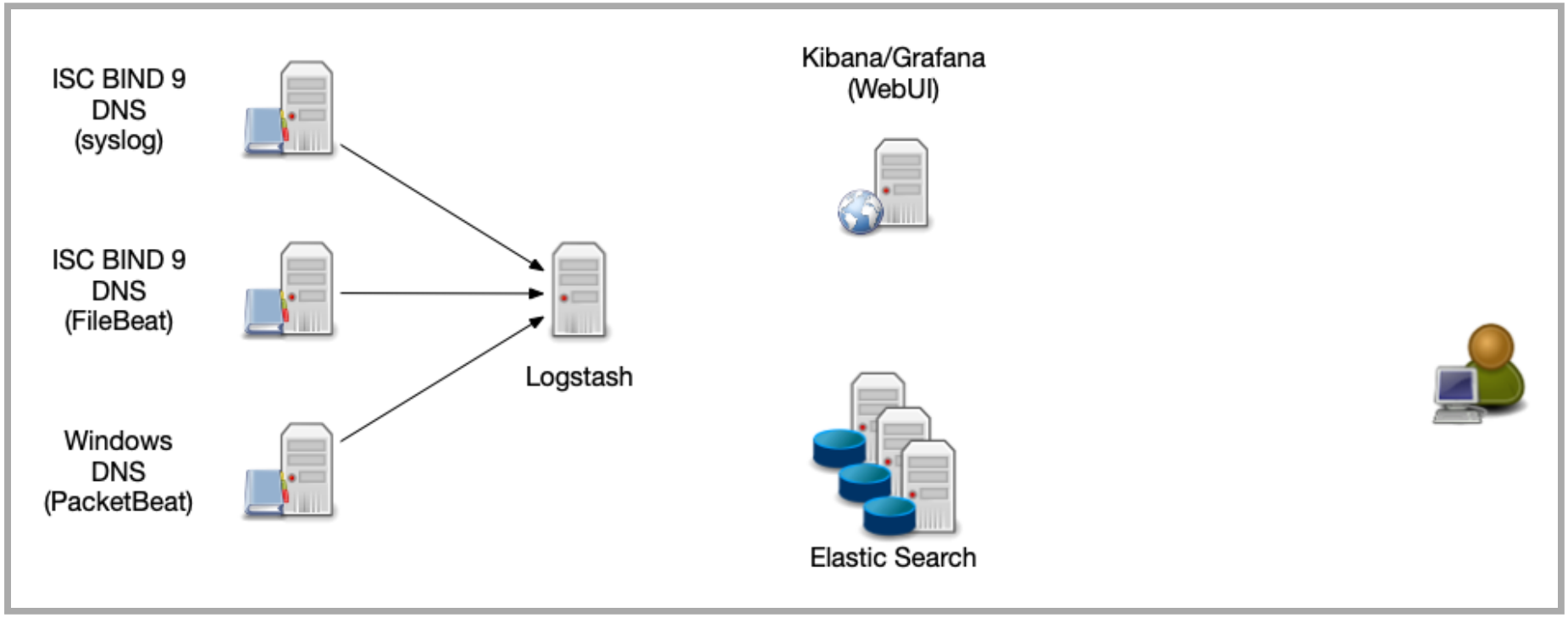

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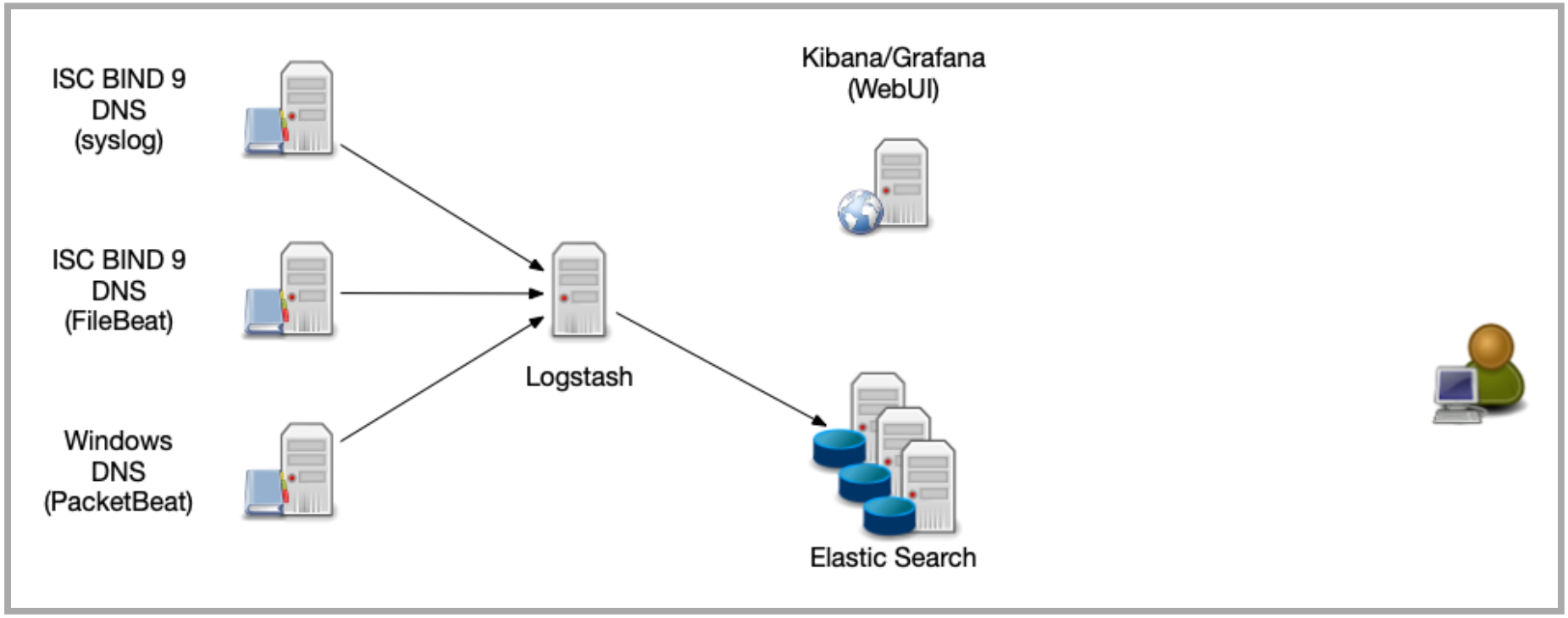

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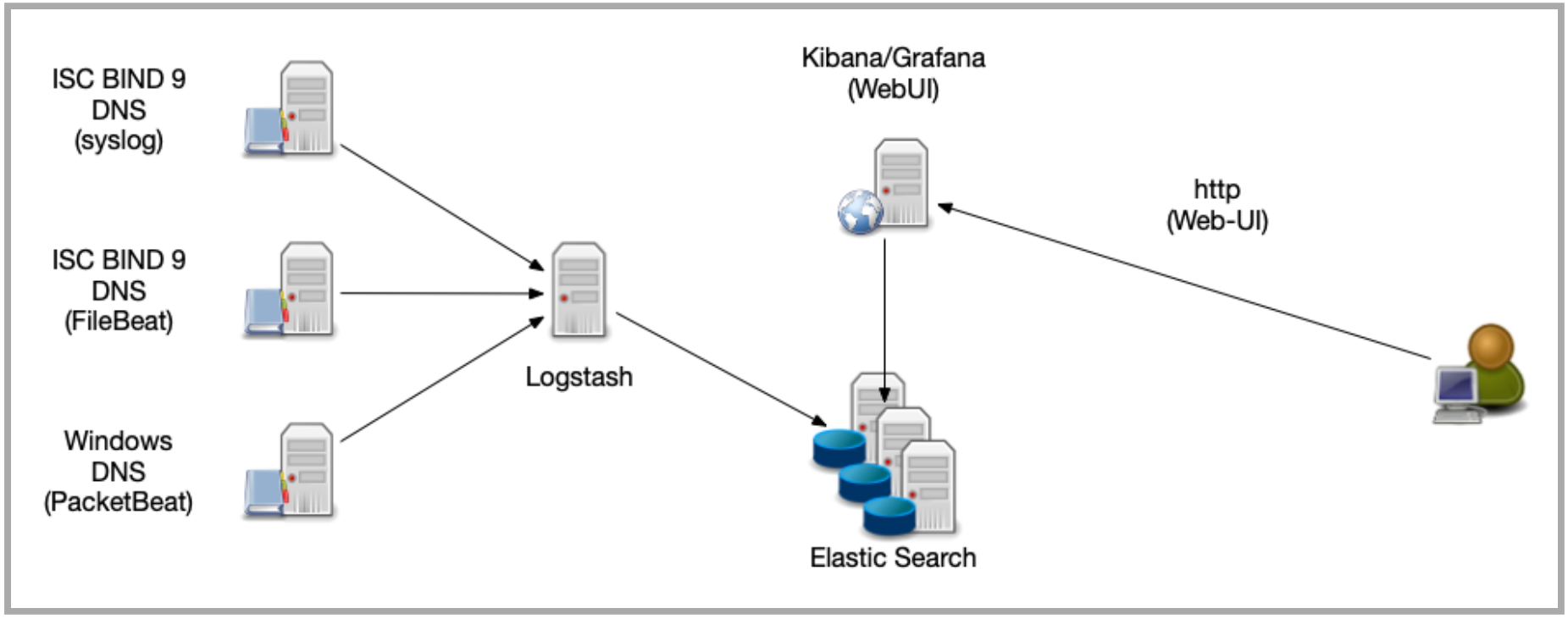
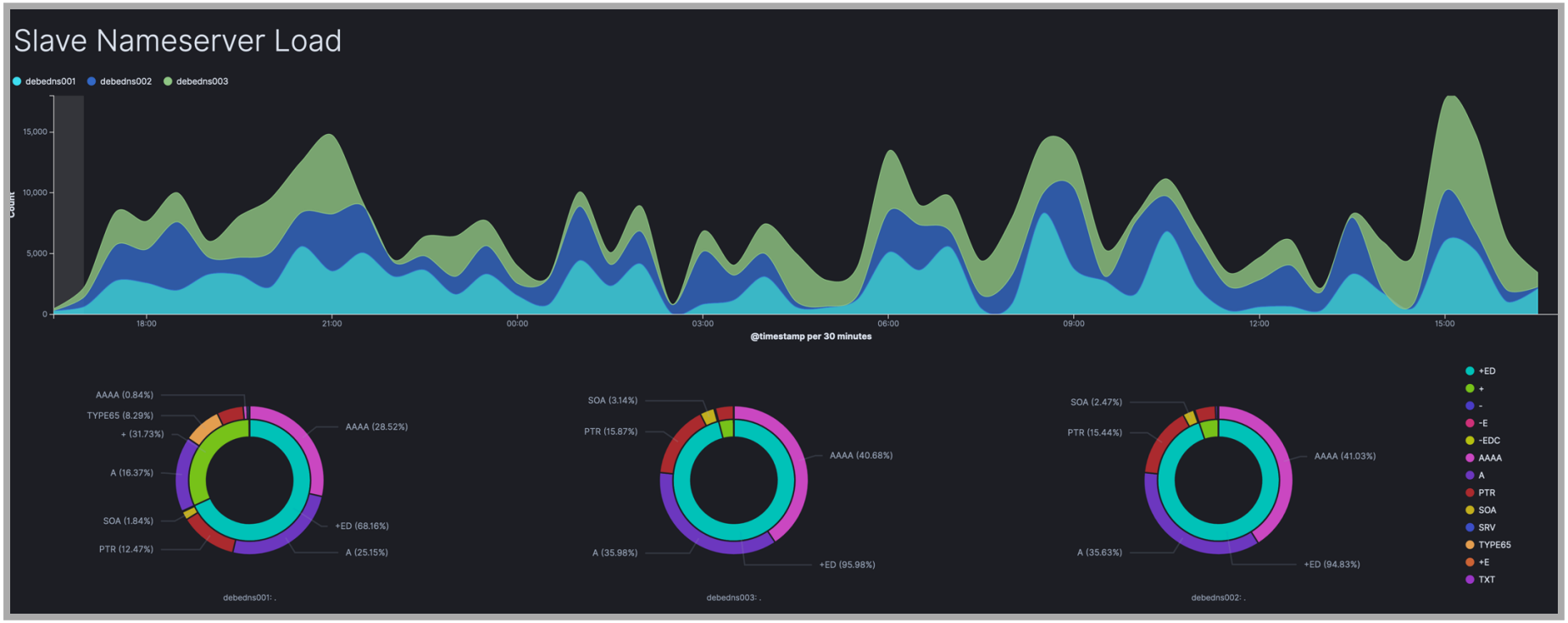


# Log-Stash Data Sources

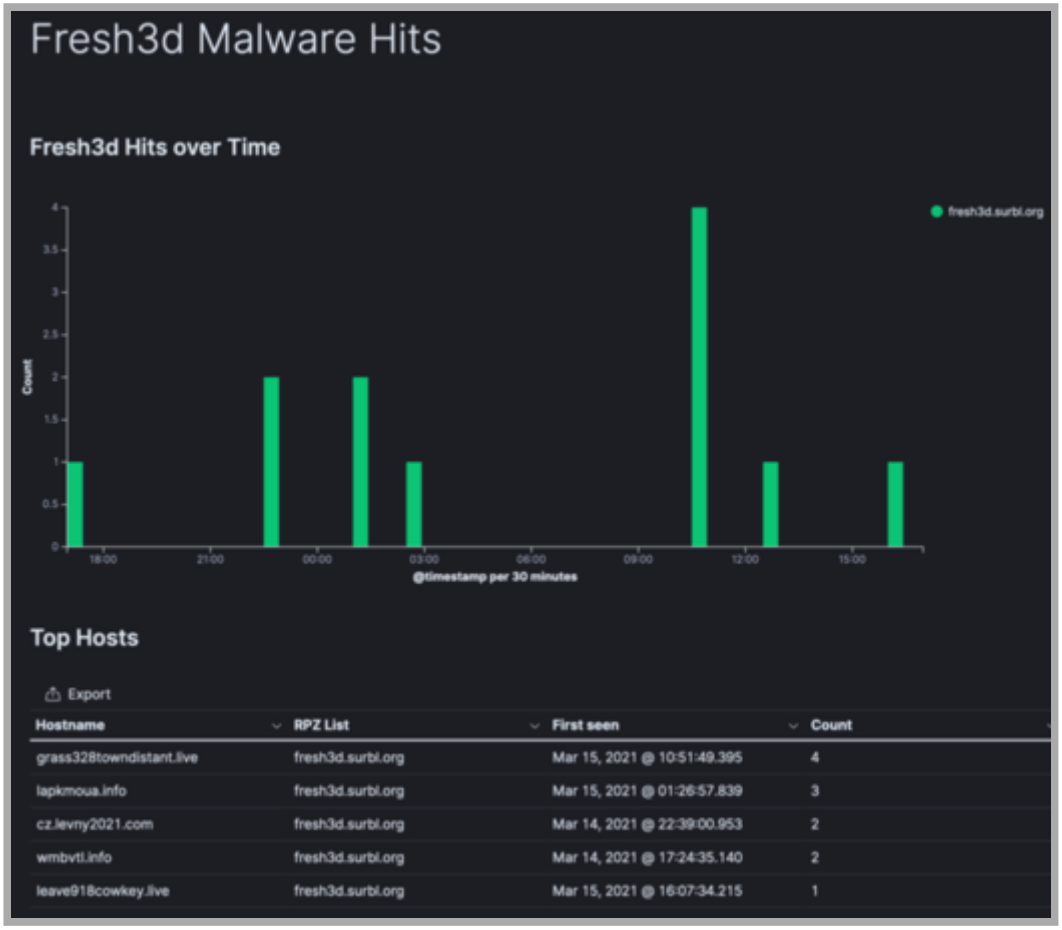
- Syslog - the DNS server sends the log information via syslog protocol to the Logstash server
- FileBeat (https://www.elastic.co/beats/filebeat) - An agent on the DNS server reads the log file and forwards the data to the Logstash-Server
- PacketBeat (https://www.elastic.co/beats/packetbeat) reads data directly from the network (pcap) and send it as structured log to Logstash

# Kibana Visualization - DNS Server Load



# Kibana Visualization - DNS Query Types

# Kibana Visualization - Malware RPZ Hits



# BIND 9 logs and remote syslog best practice

# Central Log Server

- A central log server helps correlating log events and central log analysis
- Log data can be transferred via syslog (push) or Systemd-Journal (push or pull)
- Use TLS transport security for sending log data over untrusted networks
- Central server should store the data in a structured way
  - Database (SQL or noSQL)
  - for large amounts of log data, the central server might be a cluster of multiple machines

# Plan you logging

- estimate the number of events per seconds
  - plan for the worst case (DDoS attack)
- Estimate the size of log messages that need to be stored (~ 100-150 Byte per message)
- Estimate the load
  - Can your network sustain the data rate?
  - Does this log collection will have an performance (CPU, Network, RAM) impact on the BIND 9 DNS server?
  - Can the central server process the data fast enough (normalization, structured data)
  - Can the storage keep up with the data rate (Careful with central log servers on virtual machines)?

# Plan you logging

- How long will a typical query into the data take (seconds, minutes, hours)
- How good does the central log analysis / database scale (over multiple CPU, NUMA Architectures, multiple machines)?
- How will the log data be secured (GDPR)?
  - Encryption on storage
  - Encryption on transport
  - User authentication
  - Log-Source authentication
- The log-server needs monitoring, too

# Normalize log data before sending/storing

- Unfortunately, most Syslog and BIND 9 log data is unstructured
  - Modern logging systems (rsyslog, systemd-journal) can convert the unstructured syslog data into structured data
  - Structured data is more easy to filter and search
  - If possible, structure the data already at the source (to help with filtering, see next slide)
- Send log data in the newer structured RFC 5424 format https://tools.ietf.org/html/rfc5424
- Log normalization for different formats (mmnormalize) https://www.rsyslog.com/log-normalization-for-different-formats/

# Filter before sending

- Some BIND 9 categories can be very "chatty"
  - during an attack (DDoS), the log data can overload a logging server (or the network, adding to the performance pain)
- Try to filter irrelevant information from the logs at the source (see "Artificial Ignorance" from the beginning)
  - forward the filtered and aggregated information to a central server
  - You don't want to have 1 mil. lines of the same DNS error, you want to know that this error happen 1 mil. times in a time frame

# Local buffering

- Some syslog server implementations support local buffering
  - They write the log data to local storage in case the network or the remote log server cannot keep up with the amount of data
  - Plan for enough local "buffer" storage space
  - Make sure the local "buffer" cannot fill the local storage (dedicated log buffer partition)
- Reliable Forwarding of syslog Messages with Rsyslog
  https://rsyslog.readthedocs.io/en/latest/tutorials/reliable_forwarding.html

# Log-Server security

- DNS data can contain sensitive information
  - IP addresses
  - personalized domain names (using URLs with personalized labels on wildcard domain names)
- If the log data passes untrusted networks (the Internet), encrypt the data and authenticate the log server with TLS (Encrypting Syslog Traffic with TLS https://rsyslog.readthedocs.io/en/latest/tutorials/tls_cert_summary.html)

# Log-Server security

- don't store large amounts of log data on DNS servers exposed to the Internet - forward the log data towards an internal, secured system
- Restrict access to log information (authentication)
- Keep access logs
- Delete old log data (raw data), keep aggregated data and outliers

# Log-Server security

- For security sensitive data, apply cryptographic signatures to the log messages to be able to detect tampering
  - Systemd-Journald "Forward Secure Sealing" (see part 1 of our webinar series)
  - RSyslog "Keyless Signature Infrastructure" (KSI) https://de.slideshare.net/rainergerhards1/rsyslog-vs-systemd-journal-presentation

# The human factor

- You can condense and aggregate the log information …
  - … but in the end, it has to be humans that need to check and react on the log data

*nobody can replace a good analyst with a perl script (Marcus J. Ranum)*

# Best practices for metrics to monitor for authoritative and recursive

# Metrics for recursive DNS server (DNS resolver)

- Memory consumption of the BIND 9 process (Cache Memory / Memory fragmentation)
- CPU load (load per CPU core)
- Network card utilization
- Number of clients per time unit
- Number of concurrent clients over UDP
- Number of concurrent clients over TCP
- Rate of incoming TCP queries vs. UDP queries (Clients to resolver)
- Rate of outgoing TCP queries vs. UDP queries (Resolver to authoritative server)

# Metrics for recursive DNS server (DNS resolver)

- Number of outgoing SERVFAIL responses (indicator for DNSSEC validation issues or a server issue)
- Latency of DNS answers from outside authoritative server (generic, and from a set of "well known" important domains like google.com, facebook.com etc)
- Rate of FORMERR responses towards clients (indicator for network issues, failing CPE updates, malware infected clients)

# Metrics for authoritative BIND 9 DNS Server

- Number of queries per time unit (load)
- Number of UDP and TCP queries
- Size of DNS answers (-> EDNS0 / Fragmentation)
- Percentage of truncated answers
- NXDOMAIN answers per time unit (indicator for issues with the zone content or DDoS attacks -> random subdomain attack)
- SERVFAIL answers per time unit (indicator for server mis-configuration or DNSSEC issues)

# Metrics for authoritative BIND 9 DNS Server

- Network card utilization
- CPU utilization (DNSSEC + NSEC3)
- Zone-Transfer per time unit / Errors with Zone-Transfer
- Response-Rate Limiting per client IP
- DNSSEC signing (and automated key rollover) events and errors
- SOA serial numbers on primary/secondary zones, zone update latency
- for dynamic zones: update per time unit

# Additional Information

- Example session using Log-Templater: https://webinar.defaultroutes.de/webinar/log-templater.html
- Example session using NBS: https://webinar.defaultroutes.de/webinar/nbs.html
- Information and Screenshots about BIND 9 Log-Analysis with ELK provided by NetCon Unternehmensberatung GmbH https://www.netcon-consulting.com

# Upcoming Webinars

- April 21: Session 3. Load balancing with DNSdist
- May 19: Session 4. Dynamic zones, pt1 - Basics
- June 16: Session 5. Dynamic zones, pt2 - Advanced topics

# Questions and Answers