Big Data - Labo

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Contents

1 Intro

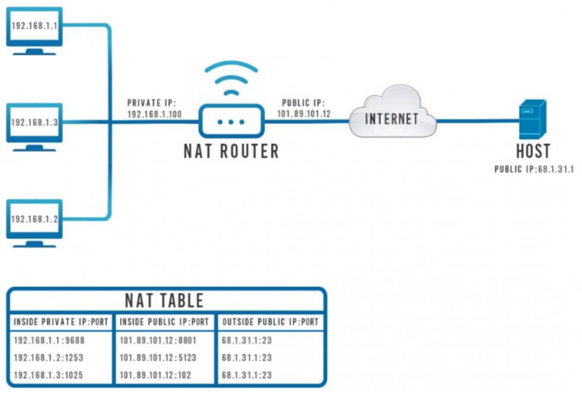
Topics:

- Linux basics + containers
- Elastic search (text search, document store)
- Linux Batch Processing & Dask
- InfluxDB (timeseries)
- Cloud services (Kafka, Kinesis, Lambda, ML services, . . .)

2 NAT-ing

2.1 NAT

= Network Address Translation



NAT TABLE

INSIDE PRIVATE IP:PORT	INSIDE PUBLIC IP:PORT	OUTSIDE PUBLIC IP:PORT
192.168.1.1:9688	101.89.101.12:8801	68.1.31.1:23
192.168.1.2:1253	101.89.101.12:5123	68.1.31.1:23
192.168.1.3:1025	101.89.101.12:102	68.1.31.1:23

Figure 1: NAT diagram

2.1.1 The problem

- We only have one (public/private) IP-address
  - Howest: 172.23.82.60
- Connecting to a server over a network:
  - Using a protocol (HTTP) which uses TCP
  - Our server has an IP address: 172.23.82.60
  - Our server is listening at port 5000
  - ⇒ `http://172.23.82.60:5000`
- Problem: We want to have multiple IP addresses
  - Student 1 wants to reach http://192.168.20.21:5000
  - Student 2 wants to reach http://192.168.20.22:5000
  - Student x wants to reach http://192.168.20.xx:5000

2.1.2 The solution

Translation is needed!

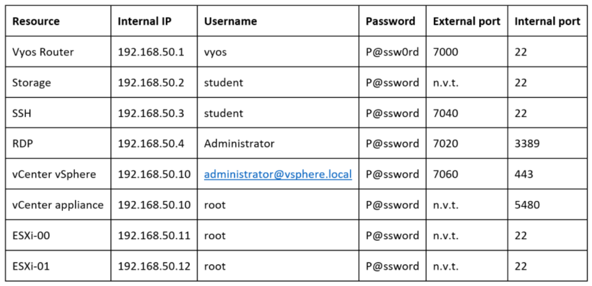
- 172.23.82.60:5000 should point to 192.168.20.21:5000
- 172.23.82.60:5001 should point to 192.168.20.22:5000
- 172.23.82.60:5xxx should point to 192.168.20.xx:5000

We can use any port, on both sides:

- 172.23.82.60:8000 can point to 192.168.20.21:5000
- 172.23.82.60:8000 can point to 192.168.20.21:3000

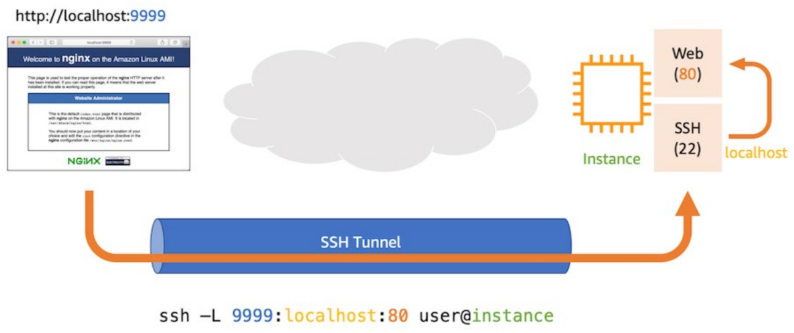
2.2 SSH Tunnel

= SSH Port Forwarding



Resource	Internal IP	Username	Password	External port	Internal port
Vyos Router	192.168.50.1	vyos	P@ssw0rd	7000	22
Storage	192.168.50.2	student	P@ssword	n.v.t.	22
SSH	192.168.50.3	student	P@ssword	7040	22
RDP	192.168.50.4	Administrator	P@ssword	7020	3389
vCenter vSphere	192.168.50.10	administrator@vsphere.local	P@ssword	7060	443
vCenter appliance	192.168.50.10	root	P@ssword	n.v.t.	5480
ESXi-00	192.168.50.11	root	P@ssword	n.v.t.	22
ESXi-01	192.168.50.12	root	P@ssword	n.v.t.	22

Figure 2: Example



```
ssh -L 9999:localhost:80 user@instance
```

Figure 3: Example: a tunnel is opened and we log into user@instance

3 Container technology

3.1 Docker

- Docker = ecosystem for creating and running containers
- Docker wants to make it possible to install and run software on any system

- Other reasons: Microservices/DevOps/Resource usage
- Docker != Container
  - Docker CLI
  - Docker Engine
  - Docker Image
  - Docker Container
  - Docker Hub
  - Docker Compose
  - Docker Swarm
  - ...

3.2 Microservices

- = A software development technique
- Structure an application as a collection of loosely coupled services
- Lightweight
- Microservices-based architectures enable continuous delivery and deployment
- `https://en.wikipedia.org/wiki/Microservices`

3.2.1 Monolithic vs Microservices

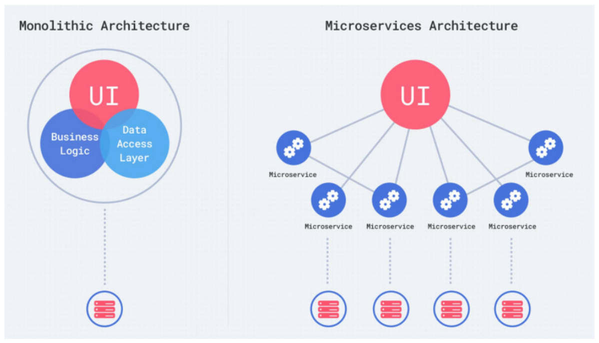


Figure 4: Monolithic architecture vs Microservices architecture

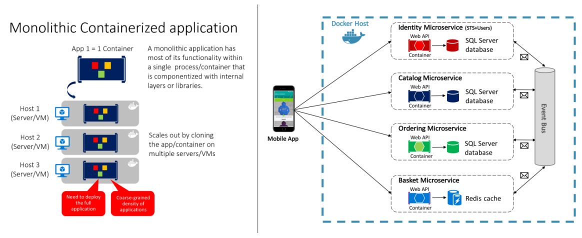

Monolithic Containerized application
App 1 = 1 Container
A monolithic application has most of its functionality within a single process/container that is componentized with internal layers or libraries.
Host 1 (Server/VM)
Host 2 (Server/VM)
Host 3 (Server/VM)
Scales out by cloning the app/container on multiple servers/VMs
Need to deploy the full application
Coarse-grained density of applications
Mobile App
Docker Host
Identity Microservice (STS+Users)
Web API
Container
SQL Server database
Catalog Microservice
Web API
Container
SQL Server database
Ordering Microservice
Web API
Container
SQL Server database
Basket Microservice
Web API
Container
Redis cache
Event Bus

Figure 5: Monolithic Containerized application

Microservices does **not** necessarily mean containerization!

3.3 Virtualization vs Containerization

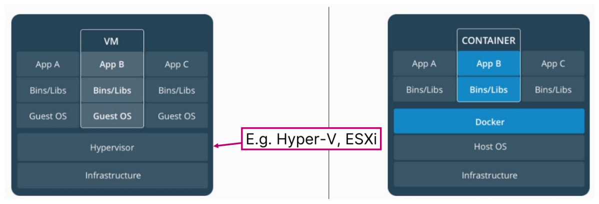


Figure 6: Virtualization vs Containerization

3.3.1 Virtualization

- = An abstraction of physical hardware turning one server into many servers
- Multiple VMs can run on the same machine
- Each VM includes a full copy of an Operating System (OS), one or more apps
- Takes a lot of space
- Can be slow to boot

3.3.2 Containerization

- = An abstraction at the app layer that packages code and dependencies together
- Multiple containers can run on the same machine, they share the OS kernel with each other, each running as isolated processes in user space.
- Takes up less space than VMs
- Boot up almost instantly

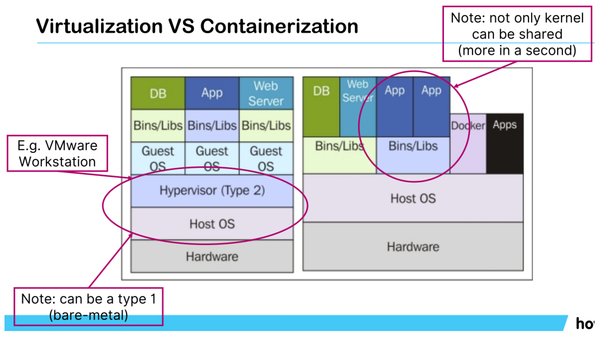


Figure 7: Schematic

3.4 Shared kernel

3.4.1 What is a kernel?

- Piece of software that offers basic functionality to the OS

- System calls: open, read, write, close, wait, exit, . . .
- A typical kernel has a few hundred system calls

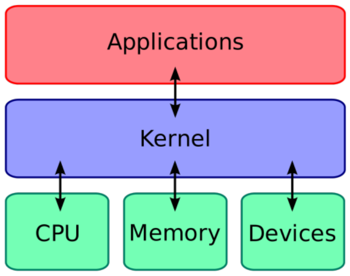


Figure 8: The kernel is the layer that communicates between hardware and applications

- Docker shares the host OS kernel
  - Host OS: Windows / MacOS / Linux
  - Shared Linux Kernel

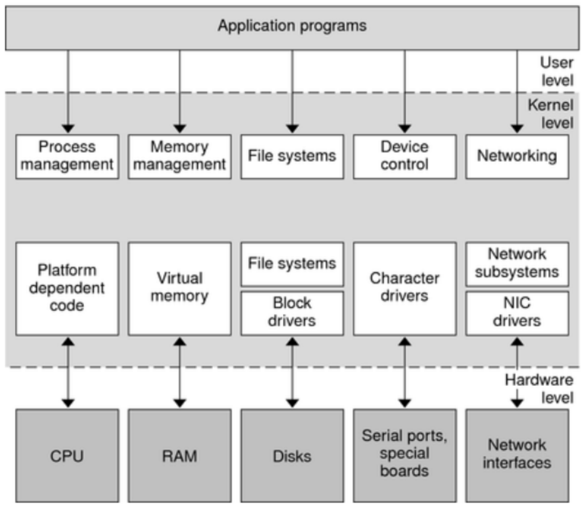


Figure 9: Kernel in detail

- The Ubuntu container requires the Linux kernel
- The Linux kernel runs in a Virtual Machine

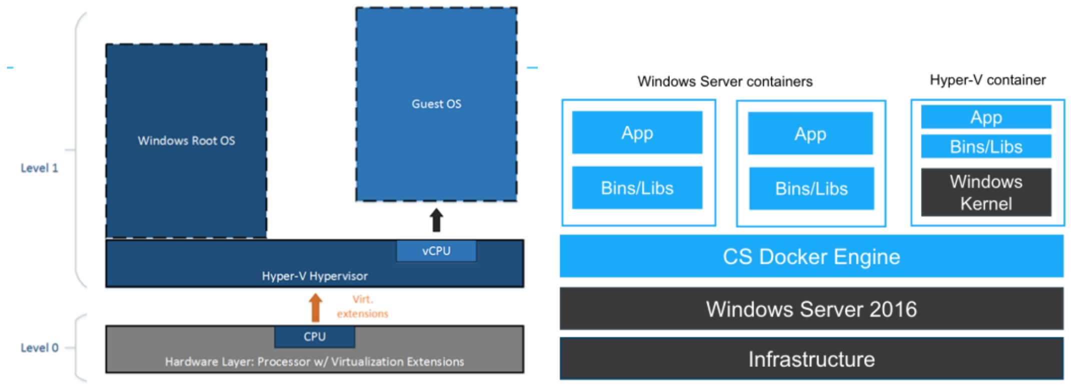


Figure 10

3.4.2 How?

Two important Linux kernel features:

- **Namespaces** are a feature of the Linux kernel that partitions kernel resources
- **cgroups** (control croups) is a Linux kernel feature that limits, accounts for, and isolates resource usage of a collection of processes

Simpler:

- Namespaces = isolating resources per process (or group of processes)
- cgroups = Limitating resource usage per process (or group of processes)

3.4.3 Namespaces

- 7 types:
  - mount, UTS, IPC, network, PID, cgroup, user
- For the process (or group of processes) it looks like there is a completely isolated set of resources

3.4.4 Containers

What is a container?

- One or more running processes (if not running anymore ⇒ container dead)
- Resources are specifically assigned to it
- The real bulding blocks: Linux kernel features
  - Namespaces
  - cgroups

3.5 Images

What is an image?

- Filesystem snapshot
- Startup command
- Layered structure **(!)**

Instance of image = container

3.5.1 Image layer

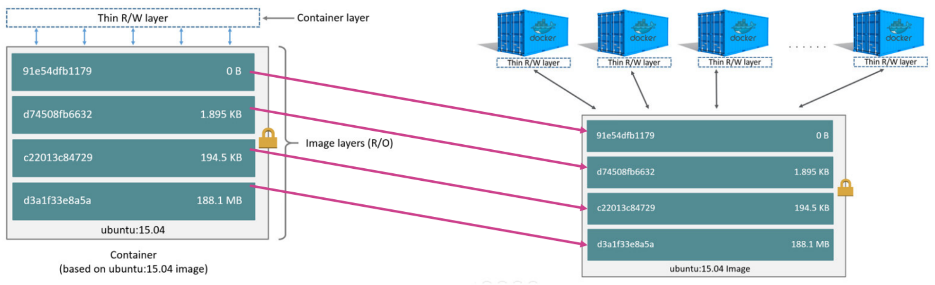


Figure 11: Image layers

- RUN, COPY, ADD
  - = new read-only layer
- Top layer = container layer
  - Writeable
- Delete container = delete container layer
  - Image will still exist
  - Peristent volumes

3.6 Docker is lightweight

- Shared kernel
- Container has no OS
- Less disk space ⇒ sharing layers
- Small community images
  - ex: Alpine Linux (small, simple, secure)
- Current Docker version is using runC (previously LXC = Linux Containers)
  - runC = tooling (written in Go) that makes it possible to create and run containers
  - runC = CLI to 'easily' access kernel features such as cgroups and namespacing
  - runC = successor of libcontainer (developed by Docker)
  - Open-sourced ⇒ better community
  - runC implements 'Open Container Initiative Runtime Specification'

– https://github.com/opencontainers/runtime-spec

Docker is ‘nothing more’ than an ecosystem about creating & running containers

3.7 Using Docker

(see slides 40-55 in 02_big_data_01_containers.pdf for basic commands)

3.7.1 View layers

With the command ‘docker history <image | container id>’ you’ll get an overview of the layers of an image.

- Every RUN, COPY, ADD adds a new read-only layer
- Make Dockerfile more efficient ⇒ create less layers

3.7.2 Make Dockerfile more efficient

Our Dockerfile, before optimalisation:

```
FROM python:3.9.1-alpine3.13
WORKDIR '/app'
RUN apk add --no-cache linux-headers g++
RUN pip install Flask # we can replace these two lines by:
RUN pip install uwsgi # RUN pip install -r requirements.txt
COPY ./ ./
RUN addgroup -S uwsgi && adduser -S uwsgi -G uwsgi
USER uwsgi
CMD ["uwsgi", "--ini", "app.ini"]
```

After optimalisation:

```
FROM python:3.9.1-alpine3.13
WORKDIR '/app'
RUN apk add --no-cache linux-headers g++
# the addgroup and adduser commands can be higher up
RUN addgroup -S uwsgi && adduser -S uwsgi -G uwsgi
# first, we copy the requirements.txt file
COPY ./requirements.txt ./
# then we install ALL packages
RUN pip install -r requirements.txt
# then we copy the remaining files
COPY ./ ./
USER uwsgi
CMD ["uwsgi", "--ini", "app.ini"]
```

3.7.3 Connecting to a database in a different container

Use ‘ip a’ to find the correct ip to use in this command:

```
docker run -p 8080:8080
    -e POSTGRES_PASSWORD=student_password
    -e POSTGRES_USER=student_user
    -e POSTGRES_DATABASE=labo
    -e POSTGRES_PORT=5432
    -e POSTGRES_HOST=ip-van-je-vm   # change this ip
    -e PORT=8080
    jouw-naam/api                   # change this
```

4 Sharding

- Index = collection of documents
- Document = data in JSON format
- Shard = A piece of an index. Index is "sharded" in blocks, a block = shard
- Primary shard = Document is primarily indexed (written) to a primary shard
- Replica shard = an asynchronous copy of the primary shard

4.1 Create index

```
{
    "settings": {
        "number_of_shards": 2,
        "number_of_replicas": 1
    }
}
```

How many shards in total: **4**

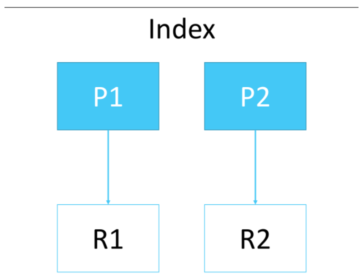


Figure 12: 4 shards: 2 primary shards with 1 replica each

4.2 Health

Health exists at shard, index and cluster level!

4.2.1 Shard health

- Green = all shards are allocated
- Yellow = all primaries are allocated but at least one replica is not
- Red = at least one primary shard is not allocated in the cluster

4.2.2 Index health

= status of the worst shard in that index

4.2.3 Cluster health

= status of the worst index in the cluster

4.3 Shard allocation

Shards states:

- Unassigned = master did not assign the shard (yet)
  - Or master is not able to assign the shard
- Initializing = master did assign the shard, creating. . .
- Started = shard is fully operational
- Relocating = shard is moving
  - Imbalance, new nodes, removed nodes, . . .

4.3.1 Unassigned

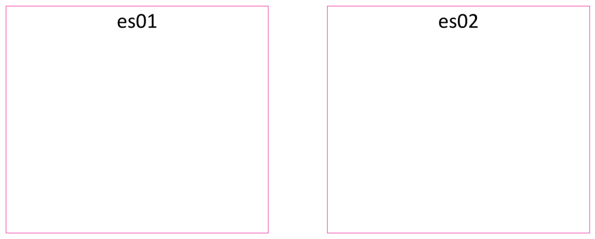


Figure 13: No shards assigned yet

4.3.2 Initializing

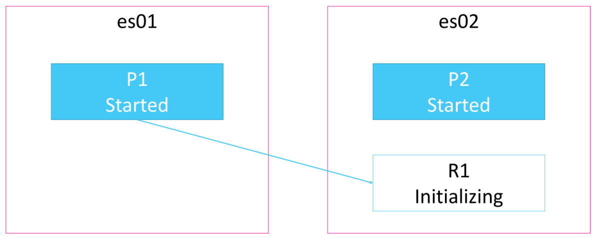


Figure 14: Creating shards

4.3.3 Started

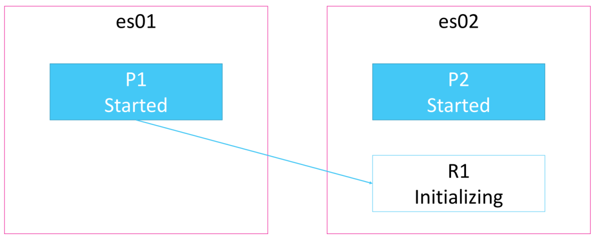


Figure 15: The primary shards have been started, replica 1 is initializing. **Cluster status = yellow**

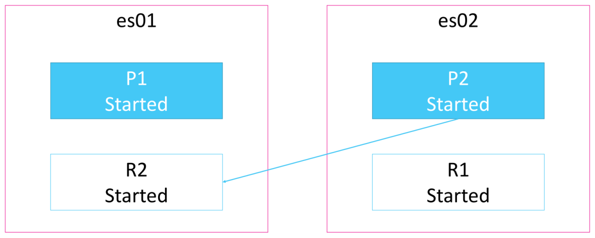


Figure 16: **Cluster status = green**

What if one of the node fails?

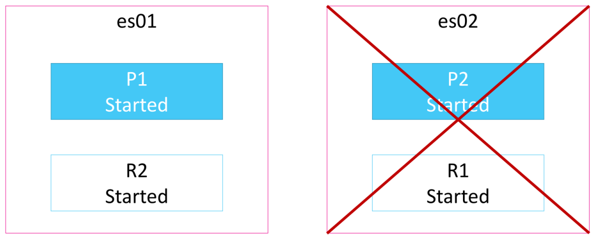


Figure 17: Situation when one node fails

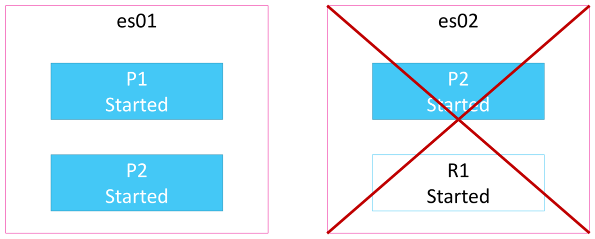


Figure 18: After some time, R2 will become a primary shard. **Cluster status = yellow**

4.3.4 Relocating

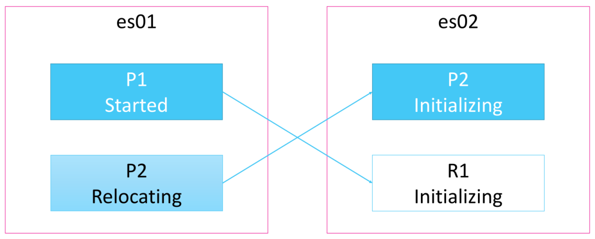


Figure 19: After es02 is restored, P2 gets relocated to its previous node

4.4 Change number of replicas

```
{
    "index": {
        "number_of_replicas": 0
    }
}
```

How many shards in total? **2**

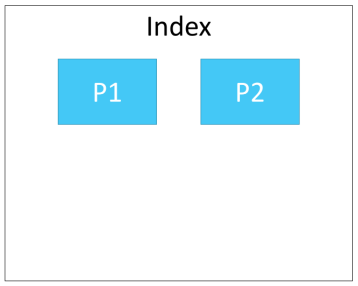


Figure 20: 2 shards total: 2 primary shards, 0 replicas each

4.4.1 Health when one fails

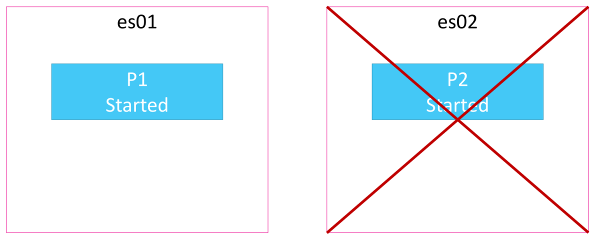


Figure 21: **Cluster status = Red**

4.5 Caveat: single node cluster

- Bootstrap checks = important settings are checked

- discovery.type=single-node
- If a node is already part of a cluster:
  - Unique node ID
  - Unique cluster ID
  - Not easy to create a new cluster

5 Linux batching + Dask

5.1 Python & data engineering/science

- Many tools, libraries (numpy, pandas)
- Not very scalable ⇒ parallellisation
- Threads/processes possible, but complex and not ideal
- What if it doesn't fit in memory?
  - To disk?
  - Possible, but complex! Some operations require everything in memory

5.2 Spark vs Dask

5.2.1 Spark

- Complex, learning curve!
- Complete 'engine', clustering
- Streaming engine
- Written in Java: uses the Java Virtual Machine (JVM) ⇒ not very accessible
- Standalone

5.2.2 Dask

- Simpler (especially if you know Python)
- Lightweight, even useful when only 1 node
- More flexible, but less performance
- Integration with other libraries
- 'The Python version of Spark'

6 TICK Stack

The TICK stack is an acronym for a platform of open source tools built to make collection, storage, graphing, and alerting on time series data incredibly easy.

The tools:

- Telegraf
- InfluxDB
- Chronograf
- Kapacitor

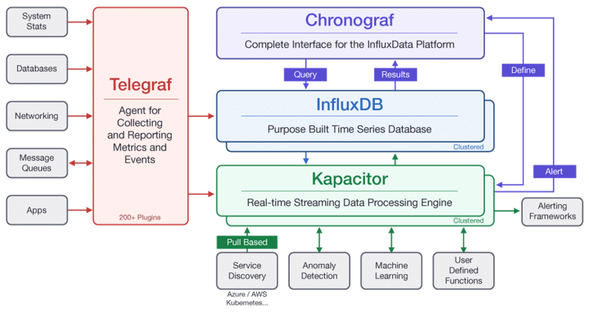


Figure 22: The components of the TICK Stack

6.1 Telegraf

- = Agent for collecting and reporting metrics and events
- Has inputs and outputs

6.2 InfluxDB

= Purpose built time series database

- Open source
- Simple HTTP API (POST, GET) with client libraries
- Somewhat similar to classic SQL, there are two versions:
  - V1: SQL & Flux: SELECT * FROM measurement WHERE tag=value
  - V2: Flux, less like SQL, better for time series data:

```
# Flux
from(bucket: "bucket")
|> range(start: v.timeRangeStart, stop: v.timeRangeStop)
|> filter(fn: (r) => r["_measurement"] == "test")
```

6.2.1 Key concepts

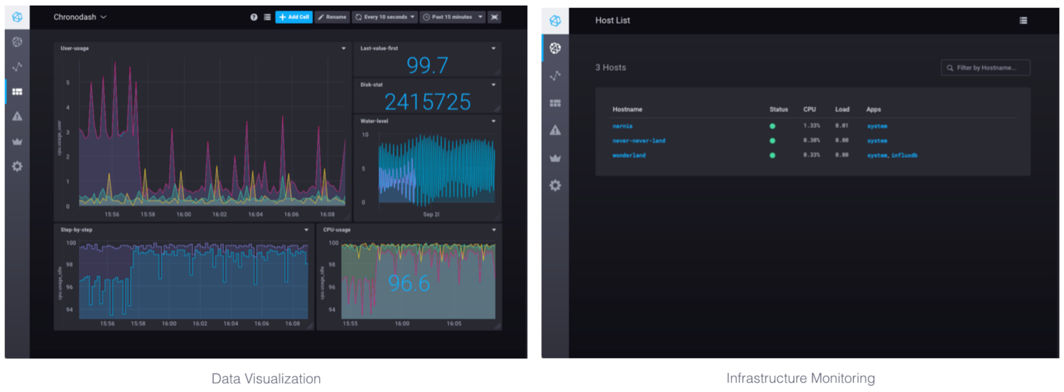
- Line protocol = a text-based format that provides the measurement, tag set, field set, and timestamp of a data point:

```
weather,location=us-midwest temperature=79,humidity=49 1591711854359
weather,location=us-midwest temperature=82,humidity=50 1591711787540
   |    -------------------- --------------------------  |
   |             |             |                         |
   |             |             |                         |
+-----------+--------+-+---------+--------------+---------+
|measurement|,tag_set| |field_set|              |timestamp|
+-----------+--------+-+---------+--------------+---------+
```

- Measurement = data that belongs together
- Timestamp = UNIX format
- Tags / Fields = key:value
- Tag = metadata
  - Tags are indexed
  - 'Fields' where you want to query on
  - Only strings!
- Field = data
  - Fields are not indexed
  - Floats, integers, strings, and booleans
- Tag set = set of tags
- Field set = set of fields

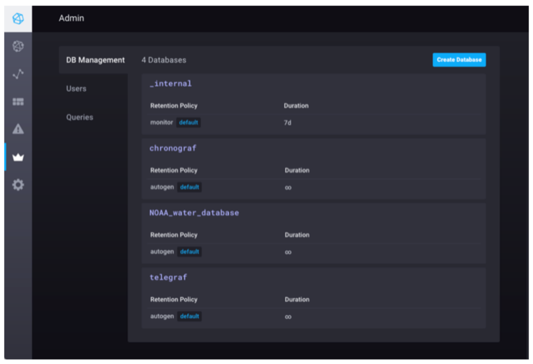
6.3 Chronograf

= A visualization tool



Hostname	Status	CPU	Load	Apps
narnia	●	1.33%	0.01	system
never-never-land	●	0.30%	0.00	system
wonderland	●	0.33%	0.00	system, influxdb

Figure 23: Data visualization and Infrastructure Monitoring



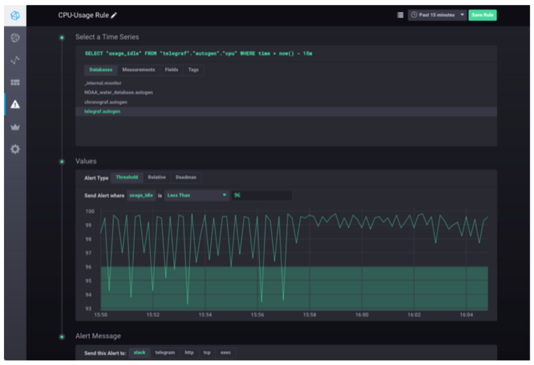
_internal	
Retention Policy	Duration
monitor default	7d

chronograf	
Retention Policy	Duration
autogen default	∞

NOAA_water_database	
Retention Policy	Duration
autogen default	∞

telegraf	
Retention Policy	Duration
autogen default	∞

Database Management



```
SELECT "usage_idle" FROM "telegraf"."autogen"."cpu" WHERE time > now() - 15m
```

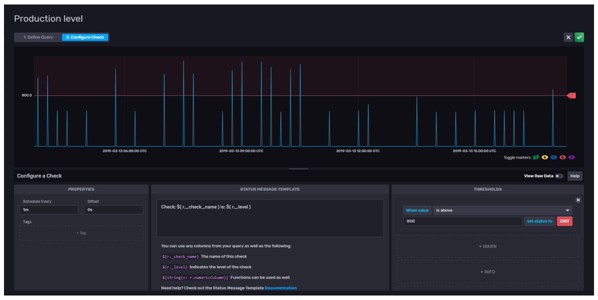
_internal.monitor
NOAA_water_database.autogen
chronograf.autogen
telegraf.autogen

Send Alert where usage_idle is Less Than 96

Alert Management

Figure 24: Database management and alert management

6.4 Kapacitor



Schedule Every: 1m
Offset: 0s
Tags

Check: ${ r._check_name } is: ${ r._level }

You can use any columns from your query as well as the following:

`${r._check_name}` The name of this check

`${r._level}` Indicates the level of the check

`${string(v: r.numericColumn)}` Functions can be used as well

Need help? Check out the Status Message Template Documentation

When value is above 800 set status to CRIT

Figure 25

6.5 Deployment models

V2

- Open source version (OSS)
  - No clustering
  - No out-of-the-box replication
- Enterprise version: expensive, contact sales
- Cloud version: cheaper, usage based
- Chronograf and InfluxDB: one component
- Multi-tenant focus

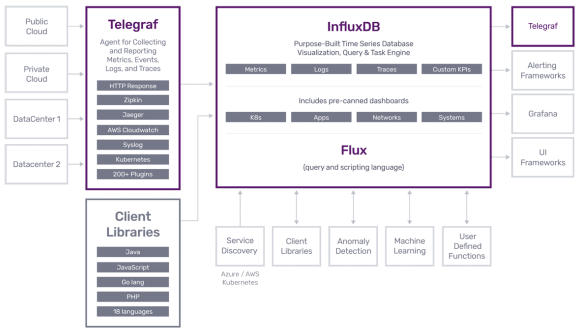
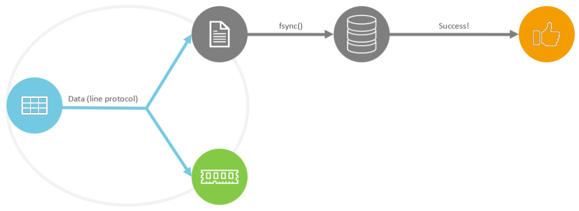


Figure 26: InfluxDB 2.0: a better graphic

6.6 Architecture of the TICK stack

6.6.1 Write Ahead Log (WAL)



- Disk optimized format (fast writes $\leftrightarrow$ slow queries)
  - Not optimized for fast queries $\Rightarrow$ memory!
- In case of a crash: replay WAL (durability $\uparrow$)
- What if we have more data than memory?
  - Out-of-memory errors (OOM)
- InfluxDB v1 vs v2 & OSS vs cloud:
  - V1 & V2 OSS: flat, simple file
  - V2 cloud: Kafka

6.6.2 Time Structured Merge Tree (TSM)

- A data structure optimized for storage and fast time-series queries
- Compressed data in columnar format
- Easy memory-mapping
- Similar to Log Structured Merge Tree (LSM)
- Field values are grouped by series key, ordered by time
- Series key = measurement, tag set and (a single) field key

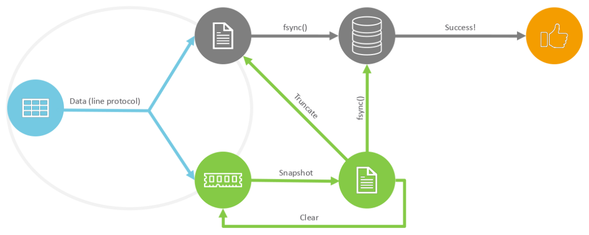


Figure 27: TSM + WAL

- Fast(er) queries: only read required series
- Compression: saved data is smaller than original (more data per node)
- Columnar: easy for memory-mapping
  - Data is cached for a limited time (solves OOM)
- What if we have many series keys (high cardinality)
  - Finding the right data will be slow!

6.6.3 Time series index (TSI)

- A data structure optimized for storage and fast query of series keys
  - TSM stores the data grouped by the series key
  - TSI stores the series keys grouped by measurement, tag and field key
- TSI answers two questions:
  - What measurements, tags and fields exists?
  - Given a measurement, tag, field, what series key exists?
- TSI stores the index in memory and on disk
  - Memory = page cache (least recently used memory)
  - Disk: writes to a WAL, compaction in the background

6.6.4 Sharding

V1:

- Directory with WAL, TSM and TSI files
- Retention policy (on database level)
- Each shard has a start and endtime
- Scalability . . . but only for InfluxDB Cloud / InfluxDB Enterprise

V2:

- Sharding in V1 has much overhead: WAL, TSM and TSI / shard
  - Too much redundant data, especially for the TSI
  - Too many writes

- Not everyone needs a retention policy
- Sharding is now implemented as a block, like in most other database systems (in OSS only 1 shard)

6.7 Pitfalls, tips & tricks

- Tips for optimal (write) performance:
  - Order your timestamps
  - Order your tags alphabetically
  - Use the right precision: seconds, milliseconds, microseconds or nanoseconds
  - Write in bulks (less fsync's)
- Duplicates: measurement, tag set & timestamp
- Tags vs. Fields
- V2 is a great product, but:
  - Documentation is far from complete
  - Bugs in client libraries, e.g. precision is neglected
  - Quick release cycle / bug fixes
- V1 vs. V2, OSS vs. Cloud vs. Enterprise

7 Mogelijke examenvragen

- Waarom gebruiken we liever "expose" dan "ports"?
- Wat is een "thing"?
- Hoe registreer je een "thing"
- Waarvoor staat TICK en licht toe.
- Leg kort uit hoe je een IOT device kan toevoegen aan amazon AWS
- Wat is het nut van "AWS lambda"?
- Bij het connecten met de AWS console van wat maak je gebruik?
- Wat is AWS IoT?
- Wat is het verschil tussen een MQTT-broken en AWS IoT?
- Wat is een lambda function?
- Wat is het verschil tussen AWS IoT Core en een MQTT broker?
- Lambda functies kunnen schrijven met de rules van AWS
- Wat zijn de grote voordelen van AWS Lambda tenopzichte van een EC2 instance?
- Wat is het nut van "virtualenv"?
- Wat is een Lambda-functie precies?
- Hoe kunnen we beter onze ElasticSearch Service beveiligen?

- Kennis over Kibana queries nog eens grondig opvragen.
- Hoe kan je een virtual enviroment aanmaken en waarom?
- Wat is onderdeel van AWS IoT en kan je gebruiken om actie te ondergaan bij een bepaald event.
- Zelfstandig een amazin IOT device kunnen creeren, en opvragen via Kibana.