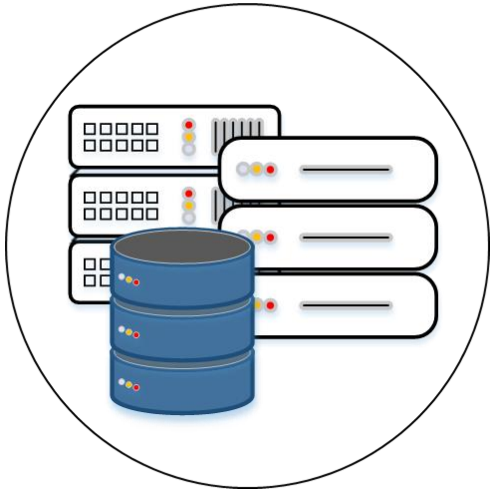
How to model stochastic behavior of failures in telco or IT systems using machine learning?

Sadegh Karimi

Hardware, estimation & maintenance



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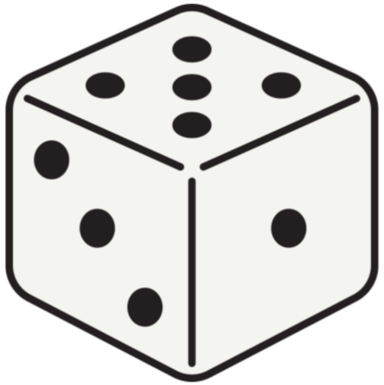
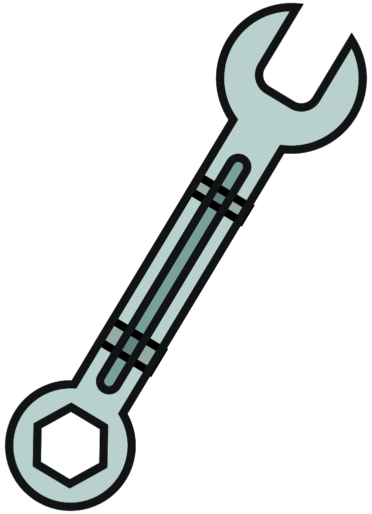


+



Problem definition

AirFrame Open Edge Server

AirScale baseband

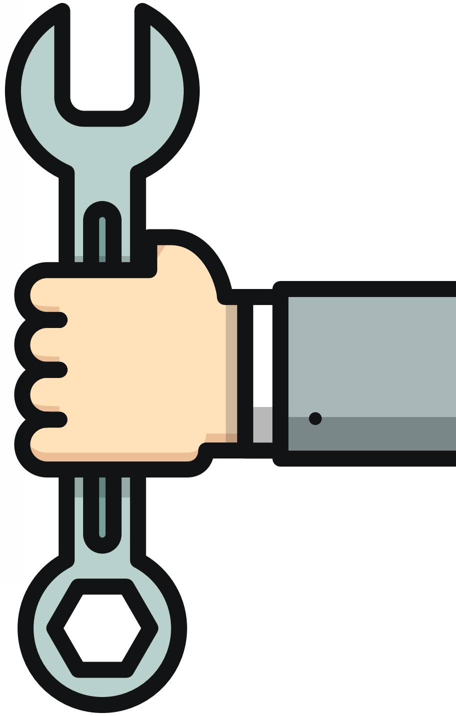
Problem definition

Corrective Maintenance (CM)

- Income loss
- Reputation damage
- Less resource planning
- Expensive repairs
- Longer downtime

Preventive Maintenance (PM)

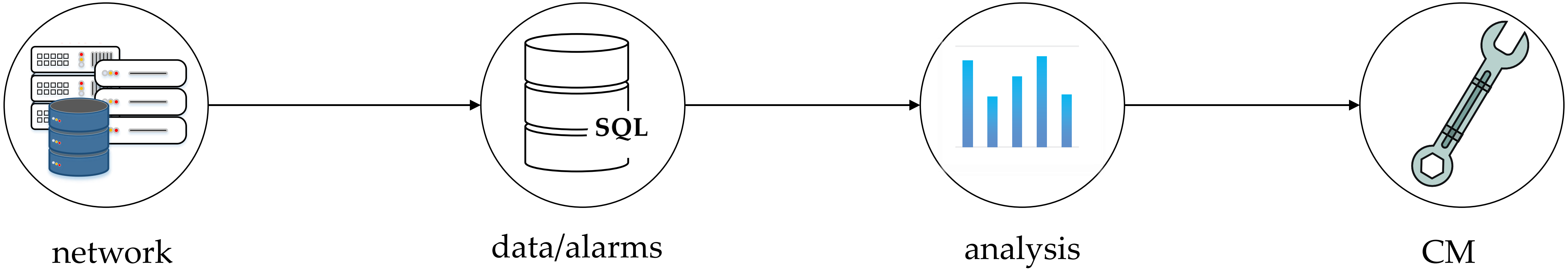
- Prevent income loss
- Prevent reputation damage
- More resource planning
- Prevent expensive repairs
- Shorter downtime



Problem definition

Conventional Method

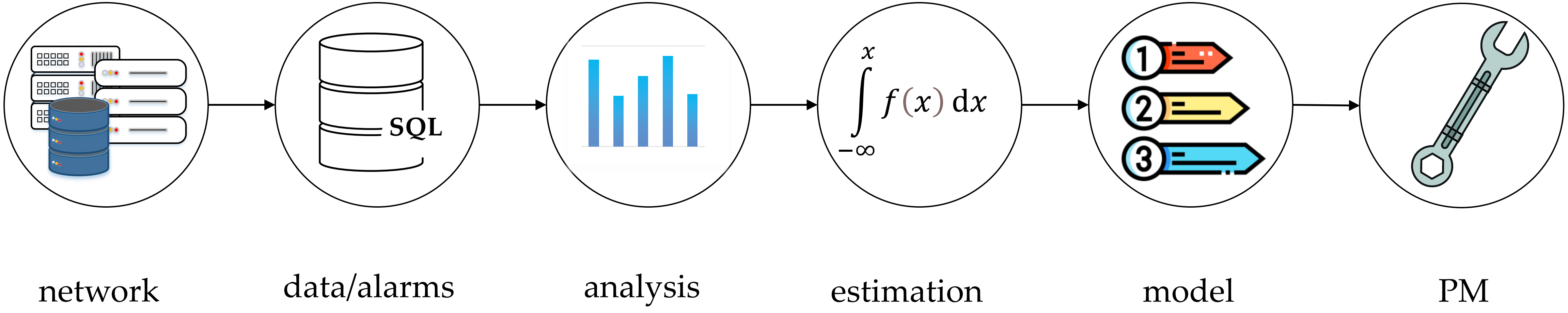
- Failure happens, then perform the fix
- Perform PM on regular basis
- CM is playing active role



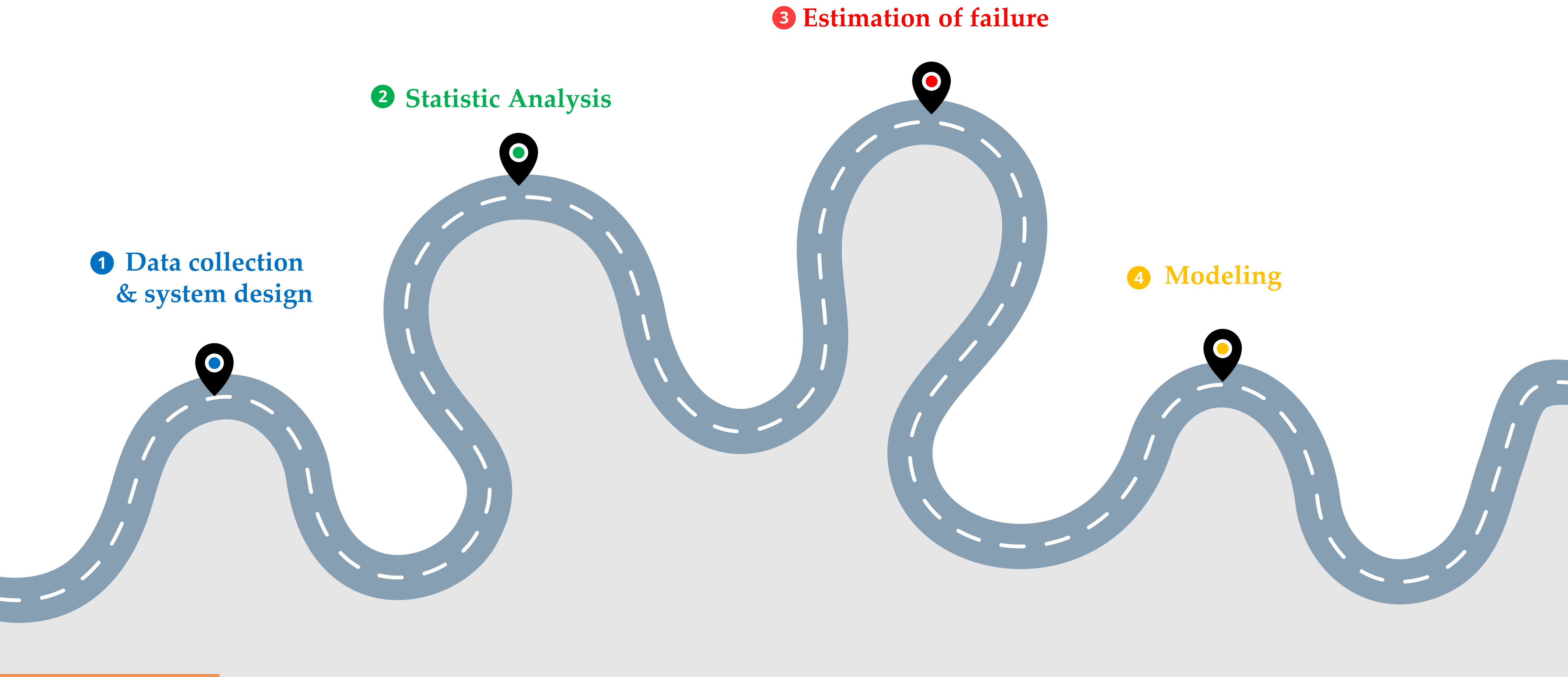
Problem definition

This method:

- Anticipate the failure, fix it before happens
- PM is playing active role



Roadmap

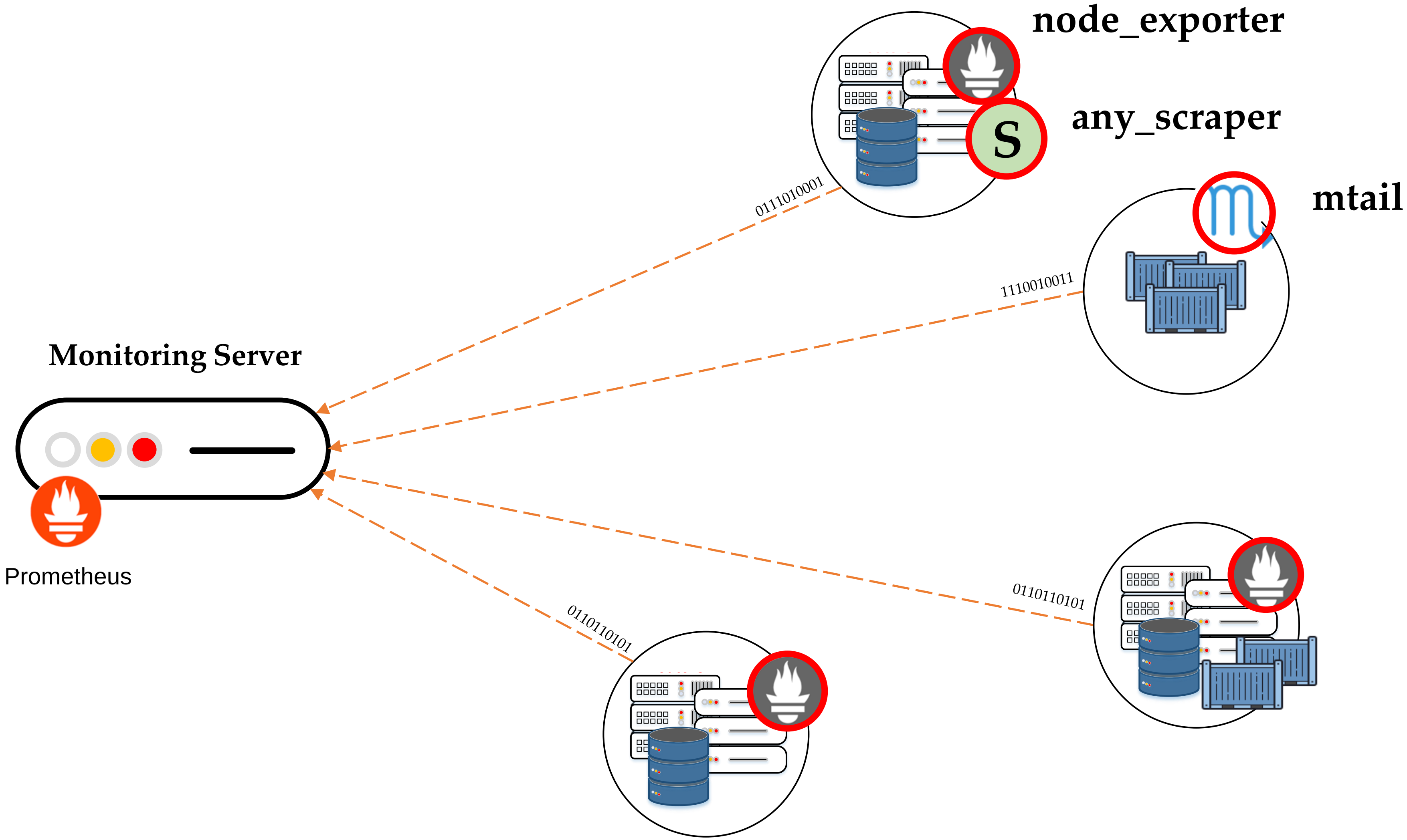


1 Data collection & system design
2 Statistic Analysis
3 Estimation of failure
4 Modeling

Data collection
& system design

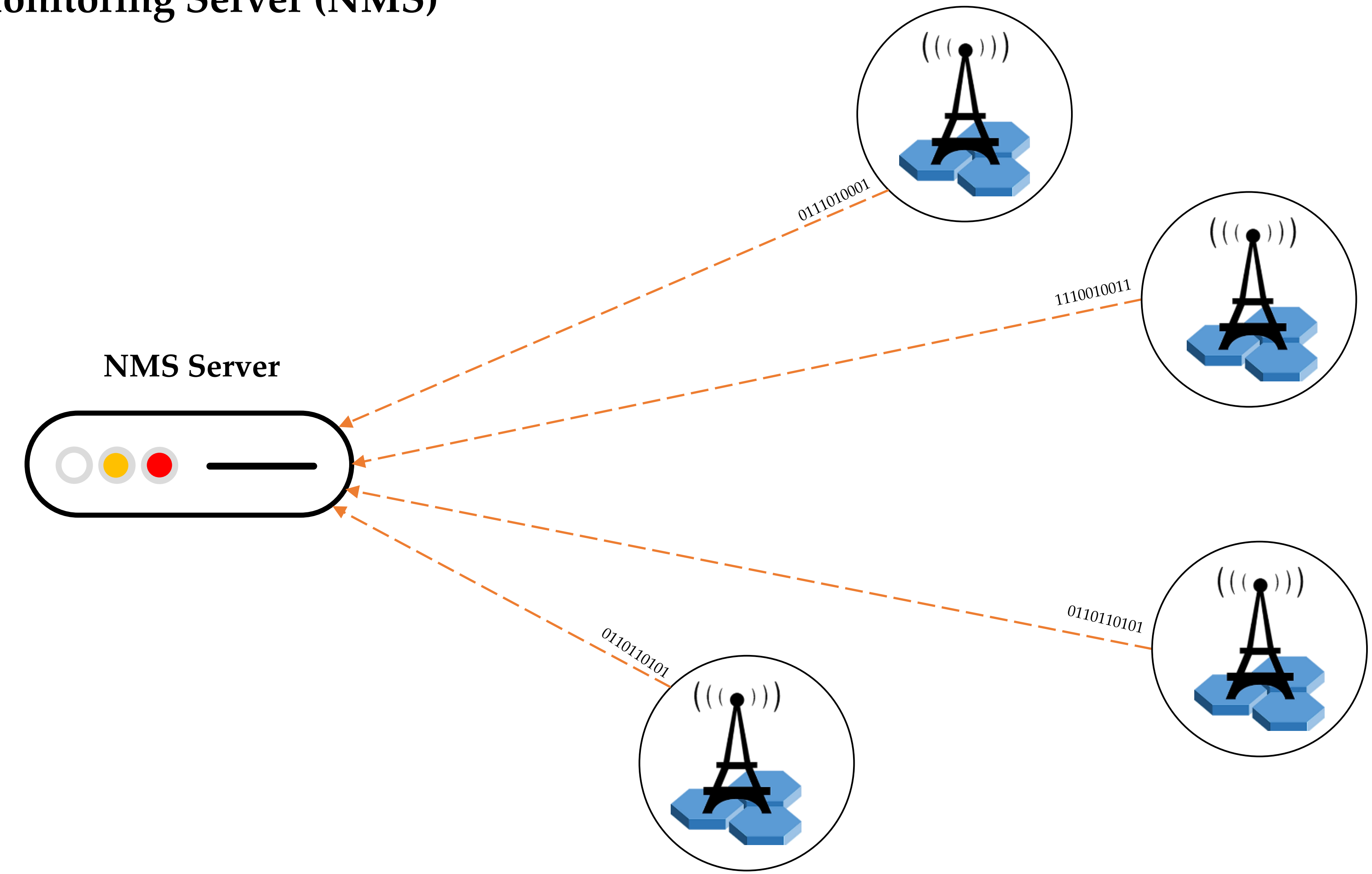
Data Collection

Method: **Prometheus**

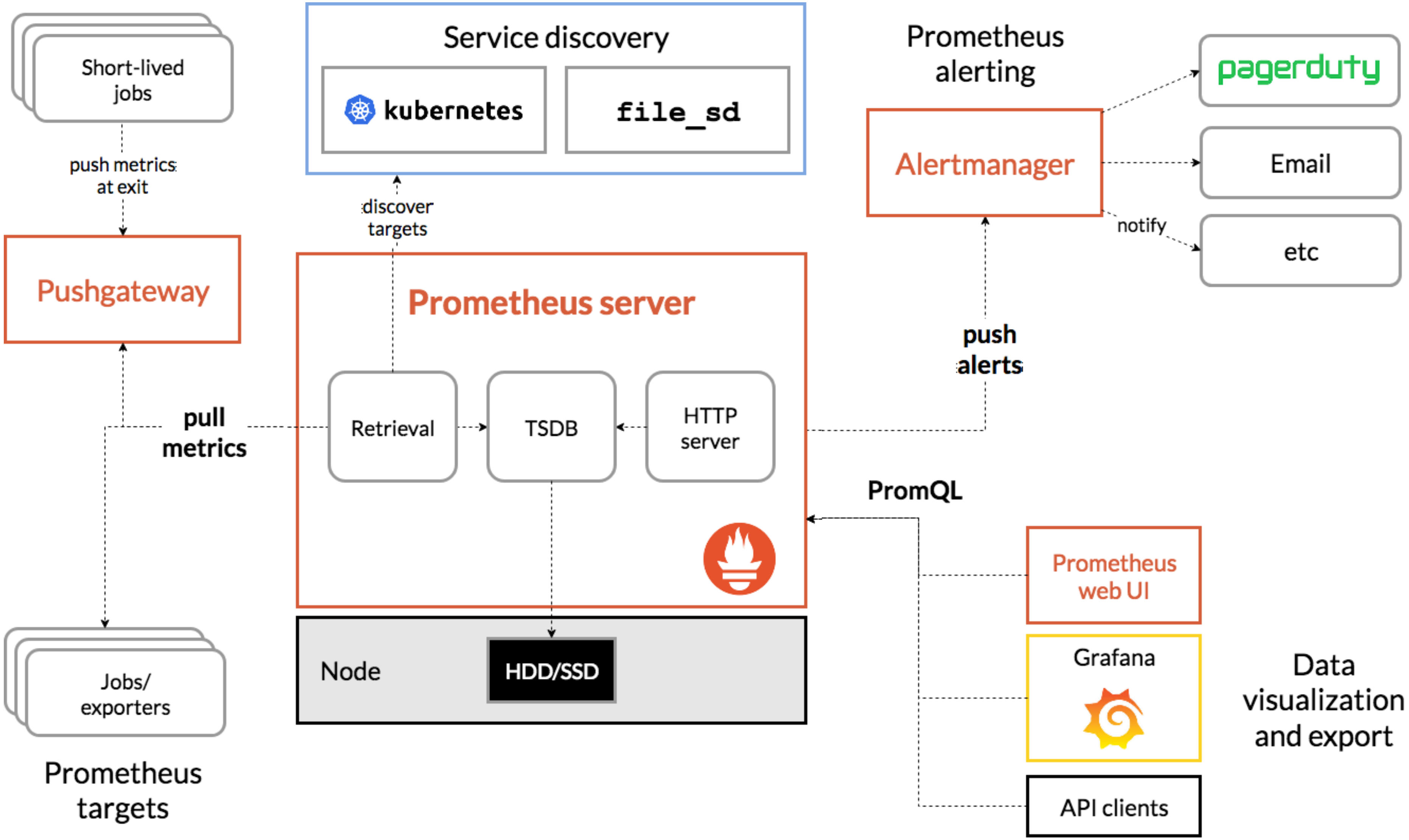


Data Collection

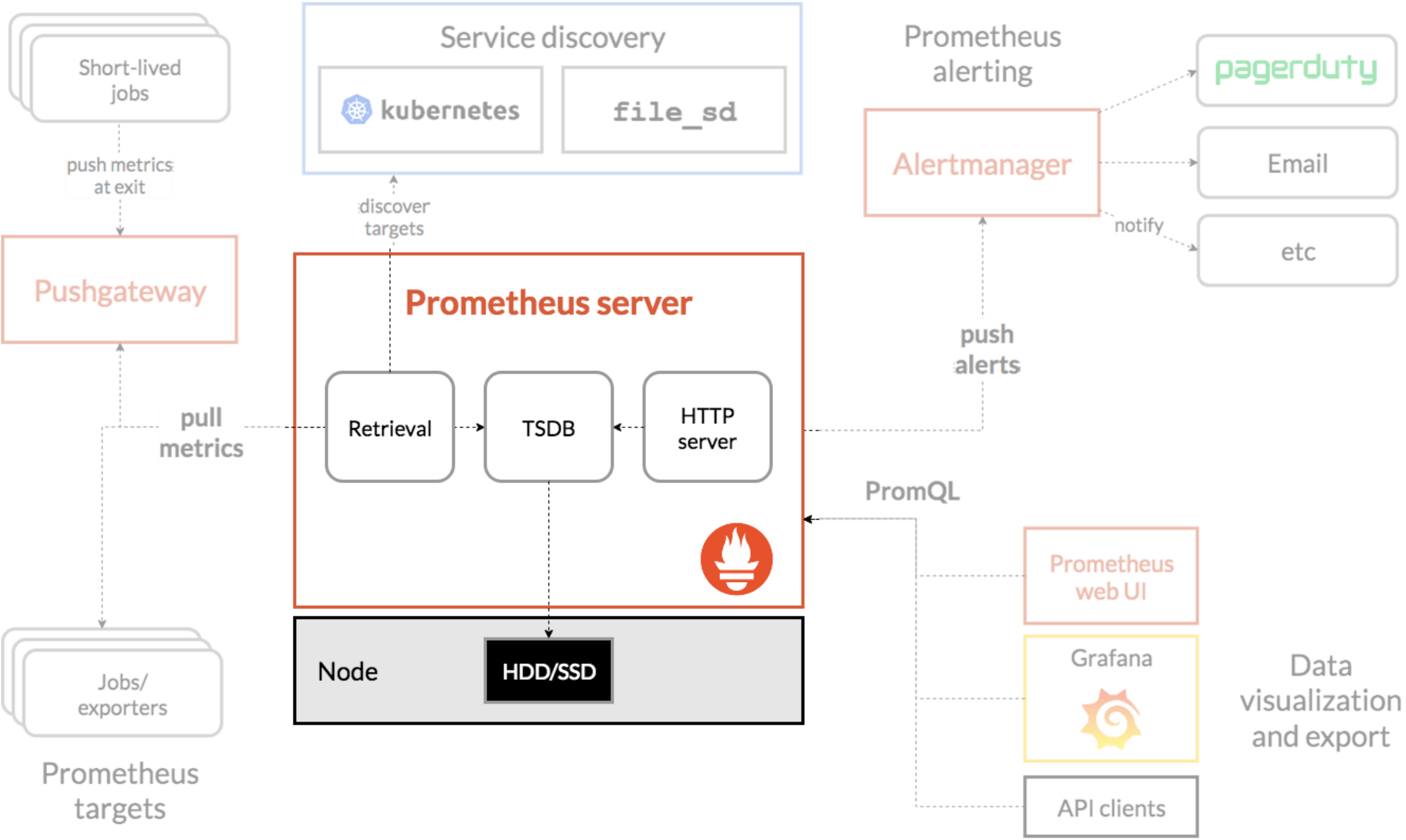
Method: **Network Monitoring Server (NMS)**



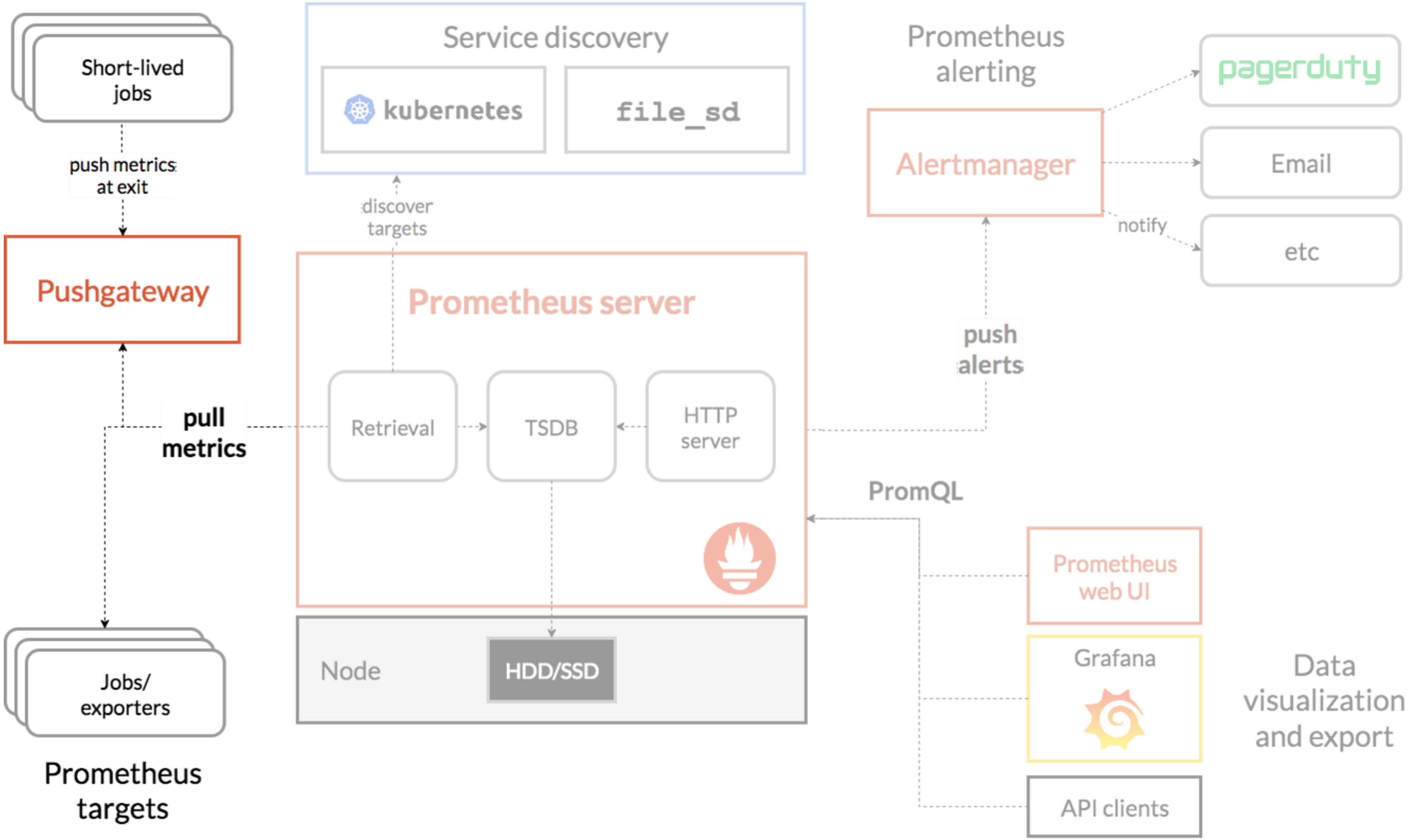
What is Prometheus?



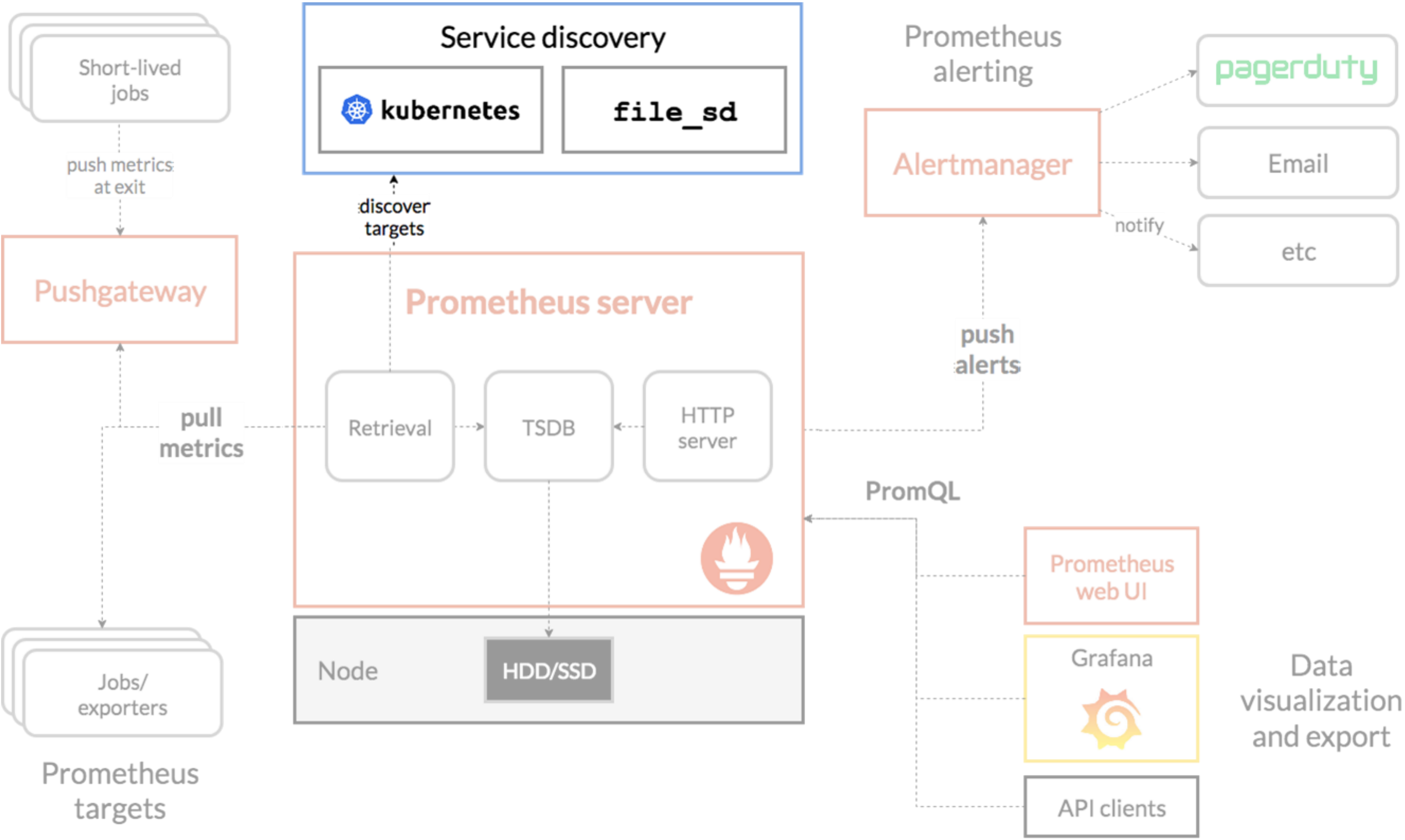
What is Prometheus?



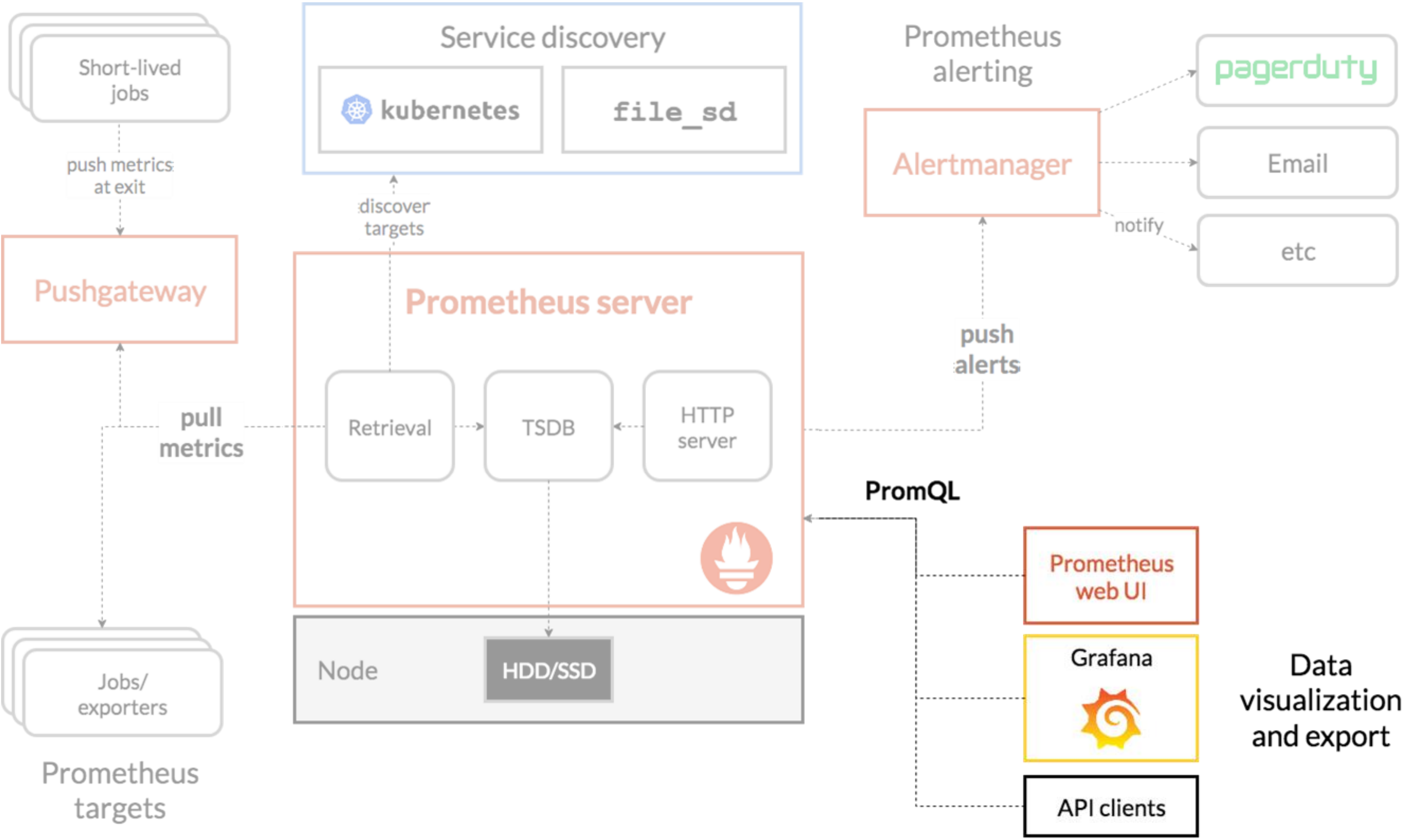
What is Prometheus?



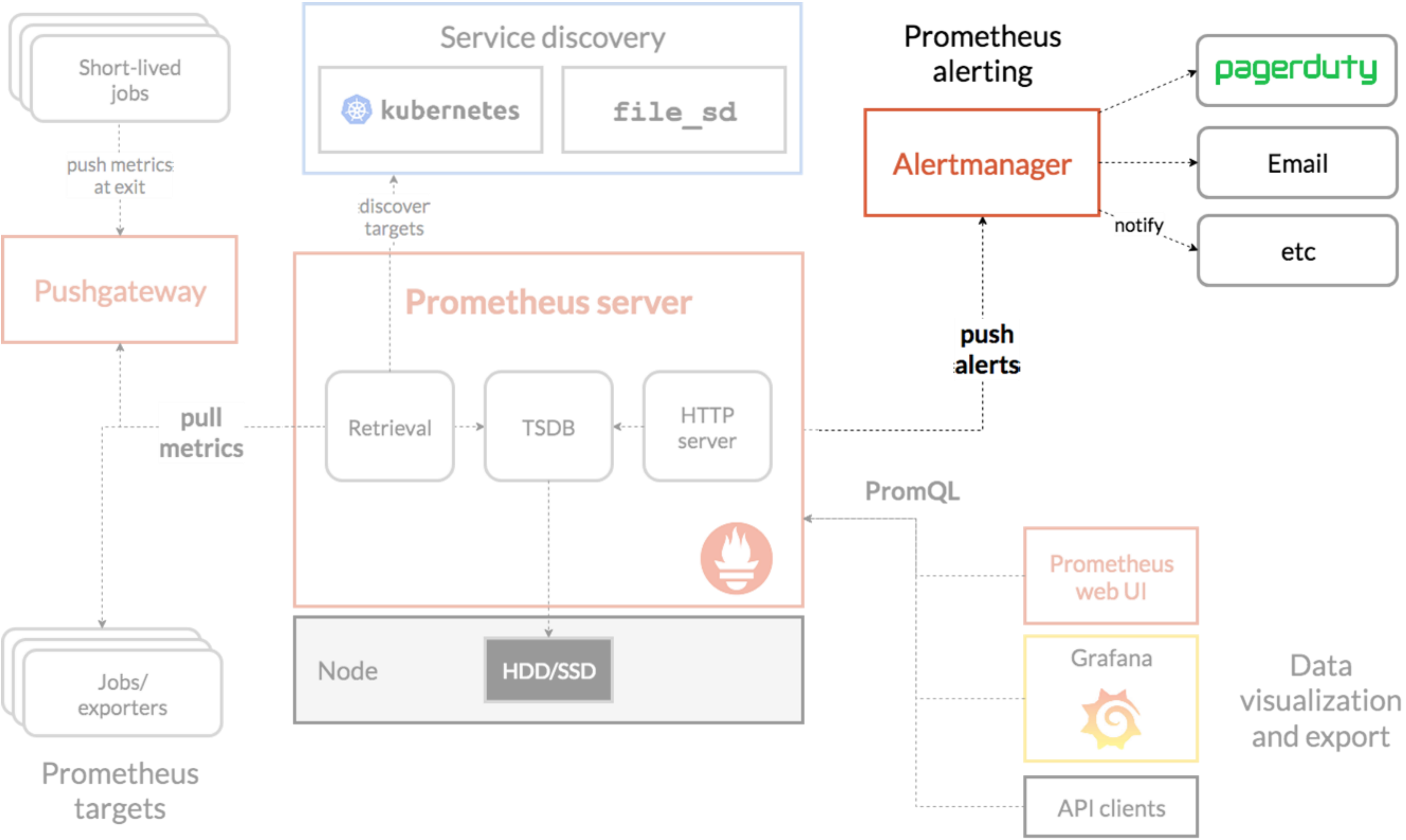
What is Prometheus?



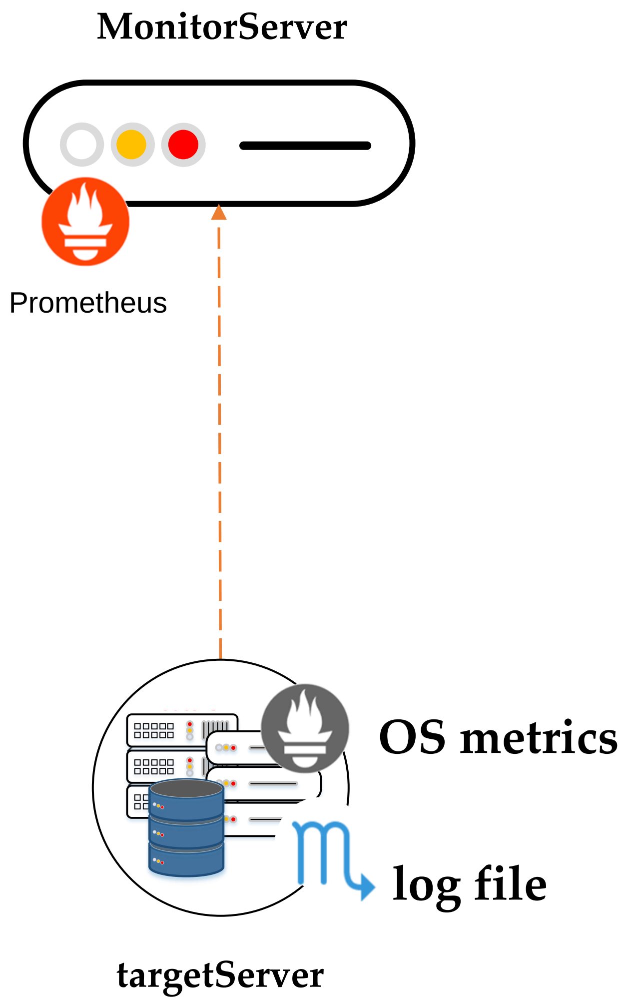
What is Prometheus?



What is Prometheus?



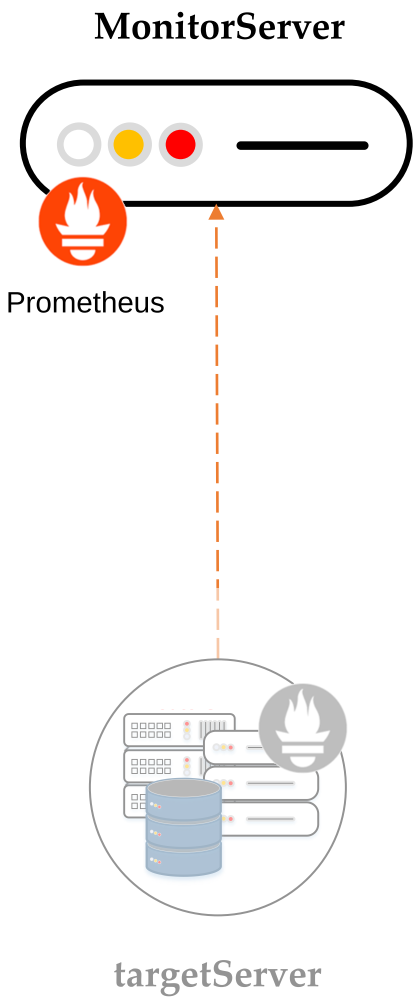
Prometheus configuration



Prometheus configuration

Terminal - MonitorServer

```
codedive@MonitorServer:~$ sudo wget https://github.com/prometheus/prometheus/releases/
download/v2.37.2/prometheus-2.37.2.linux-amd64.tar.gz
codedive@MonitorServer:~$
codedive@MonitorServer:~$ sudo mkdir /usr/local/bin/Prometheus
codedive@MonitorServer:~$
codedive@MonitorServer:~$ mv prometheus-2.37.2.linux-amd64.tar.gz /usr/local/bin/Prometheus
codedive@MonitorServer:~$ cd /usr/local/bin/Prometheus
codedive@MonitorServer:~$
codedive@MonitorServer:~$ tar xvfz prometheus-2.37.2.linux-amd64.tar.gz
codedive@MonitorServer:~$ cd prometheus-2.37.2.linux-amd64
codedive@MonitorServer:~$
codedive@MonitorServer:~$ vim prometheus.yml
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$ sudo ufw allow 9090/tcp
codedive@MonitorServer:~$
codedive@MonitorServer:~$ ./prometheus --config.file=prometheus.yml > /dev/null 2>&1 &
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$ vim /etc/systemd/system/prometheus.service
```



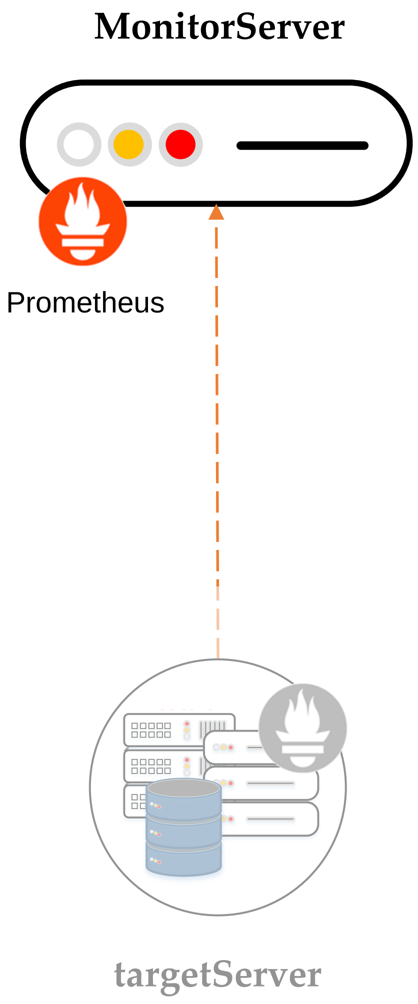
Prometheus configuration

Terminal – vim /etc/systemd/system/prometheus.service

```
[Unit]
      Description=Prometheus
      User=root
      Group=root
      After=local-fs.target network-online.target network.target
      Wants=local-fs.target network-online.target network.target

[Service]
      Type=simple
      Restart=on-failure
      ExecStart=/usr/local/bin/prometheus/prometheus-2.37.2.linux-amd64/prometheus --config.file=
      /usr/local/bin/prometheus/prometheus-2.37.2.linux-amd64/prometheus.yml

[Install]
       WantedBy=multi-user.target
```



Prometheus configuration

Terminal – MonitorServer

```
codedive@MonitorServer:~$ systemctl daemon-reload
codedive@MonitorServer:~$ systemctl start Prometheus
codedive@MonitorServer:~$ systemctl status prometheus
codedive@MonitorServer:~$ systemctl enable prometheus
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$
codedive@MonitorServer:~$
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codedive@MonitorServer:~$
```

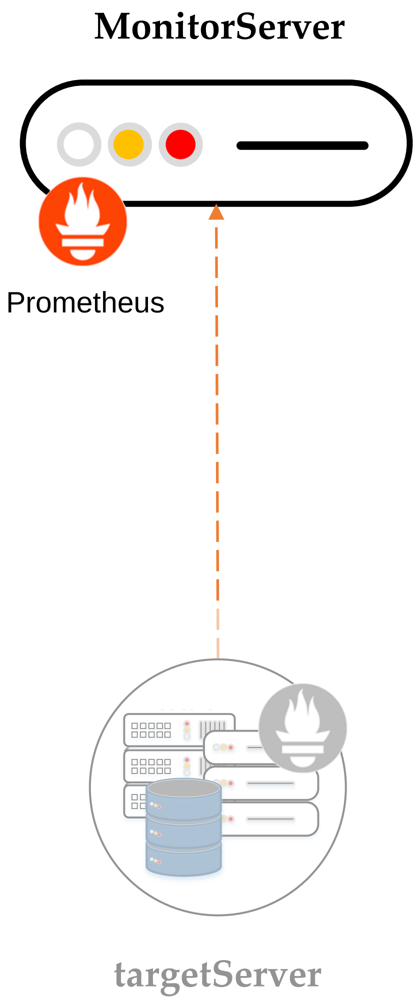

Prometheus configuration

Terminal – TargetServer

```
codedive@TargetServer:~$
codedive@TargetServer:~$ wget https://github.com/prometheus/node_exporter/releases/download
/v1.4.0/node_exporter-1.4.0.linux-amd64.tar.gz
codedive@TargetServer:~$ tar xvfz node_exporter-1.4.0.linux-amd64.tar.gz
codedive@TargetServer:~$
codedive@TargetServer:~$ cd node_exporter-1.4.0.linux-amd64
codedive@TargetServer:~$ mv node_exporter /usr/local/bin/node_exporter
codedive@TargetServer:~$
codedive@TargetServer:~$ sudo ufw allow 8081/tcp
codedive@TargetServer:~$
codedive@TargetServer:~$ node_exporter --web.listen-address 0.0.0.0:8081 > /dev/null 2>&1 &
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
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codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
```
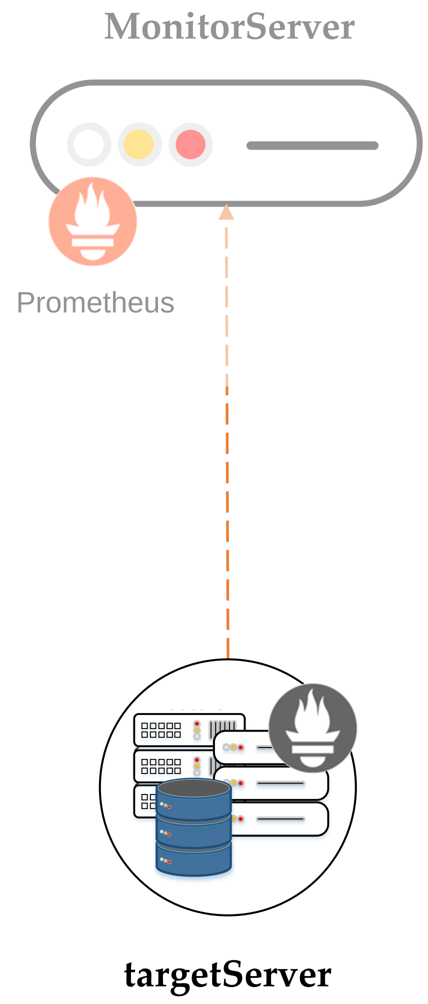
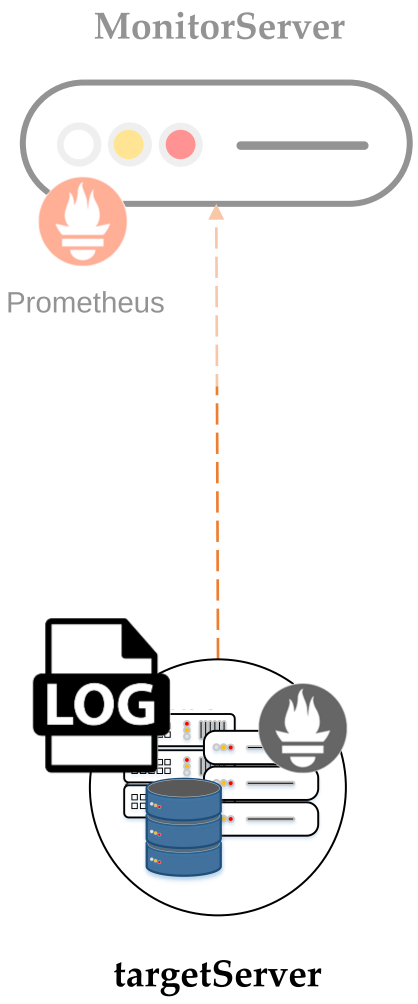



Prometheus configuration

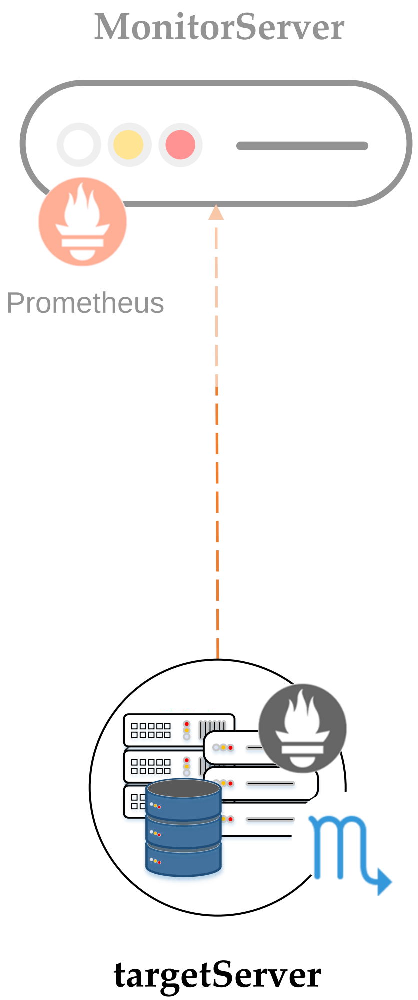
```
Terminal - TargetServer

codedive@TargetServer:~$ cat anylogfile.log
time, ip,hw alarms, cpu errors, low volt, overheat alarm, fan degraded, priority, failure
2022211500      86.245.244.226 0          0     2     1     1     3     1
2022220912      242.254.113.85 0          0     1     3     3     3     1
2022231054      180.67.216.32  2          0     2     0     0     2     2
2022251123      17.164.18.174  2          0     1     2     2     3     2
2022261254      16.75.147.107  1          0     1     1     1     4     1
2022281333      166.42.237.79  0          0     2     1     0     4     1
2022291531      240.151.80.141 1          0     3     0     0     1     2
2022271723      251.187.13.90  0          0     4     3     3     2     2
2022241324      32.40.200.86   0          0     1     0     0     1     0
2022011136      106.129.137.98 0          0     2     4     3     2     2
2022031252      101.25.58.95   1          0     2     3     3     1     2
2022041521      16.10.150.63   1          2     1     3     3     2     2
2022102043      168.147.131.18 1          0     2     2     1     3     2
2022122245      230.12.118.189 1          1     1     4     3     2     3
2022141247      17.226.234.190 1          0     1     0     0     3     0
2022191539      119.159.65.0   1          0     4     0     0     3     2
2022201848      129.255.137.20 0          0     2     0     0     1     1
2022232346      172.91.66.180  1          0     1     3     3     3     2
2022232339      154.92.117.111 1          0     3     1     1     2     1
2022251449      12.103.196.116 1          0     1     3     3     2     2
2022271049      90.205.195.153 0          0     2     0     0     1     1
2022271943      98.95.46.105   1          0     1     3     3     3     2
2022281157      158.120.7.77   1          0     3     1     1     2     1
2022292021      20.28.39.208   1          0     1     3     3     2     2
```



Prometheus configuration

Terminal – TargetServer

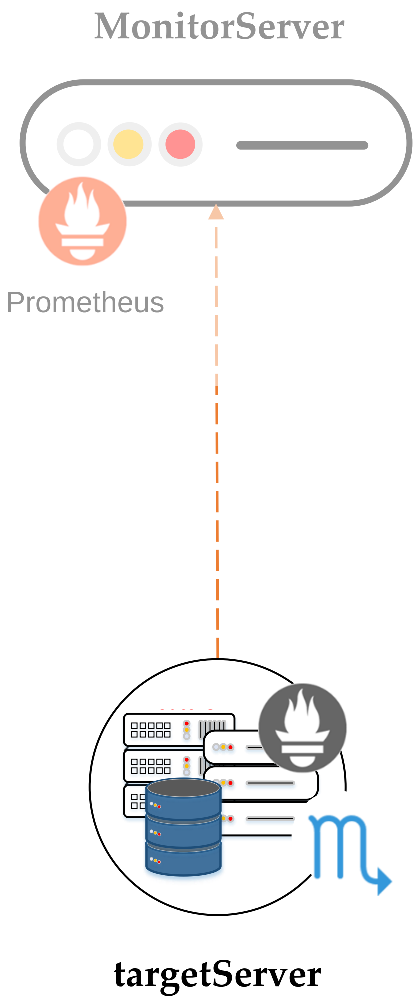
```
codedive@TargetServer:~$ apt-get update
codedive@TargetServer:~$ apt-get install mtail
codedive@TargetServer:~$ systemctl enable mtail
codedive@TargetServer:~$
codedive@TargetServer:~$ ufw allow 3903/tcp
codedive@TargetServer:~$
codedive@TargetServer:~$ vim /etc/mtail/whateverlogfile.mtail
```



Prometheus configuration

Terminal – vim /etc/mtail/whateverlogfile.mtail

```
counter hardware_alarm by ip
counter cpu_error by ip

# log_format mtail '$time, $ip, $”hw alarms”, $”cpu errors” , $”low volt”'
#                   ‘$”overheat alarm”, $”fan degraded”, $priority, $failure’;

/^/ +
#
/\s(?P<transfertime>\d+)/ +

# remote IP
/\s(?P<remoteIP>\d+\.\d+\.\d+\.\d+)/ +

# hw alarms
/\s(?P<hw_alarms>\d+)/ +

# cpu errors
/\s(?P<cpu_error>\d+)/ +

...
...
...

{
   hardware_alarm[$ip]++
   cpu_error[$ip]++
}
```



Prometheus configuration

Terminal – TargetServer

```
codedive@TargetServer:~$
codedive@TargetServer:~$ mtail  --logs /var/log/anyservice/anylogfile.log  --progs/etc/
mtail/ > /dev/null 2>&1 &
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
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codedive@TargetServer:~$
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codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
codedive@TargetServer:~$
```
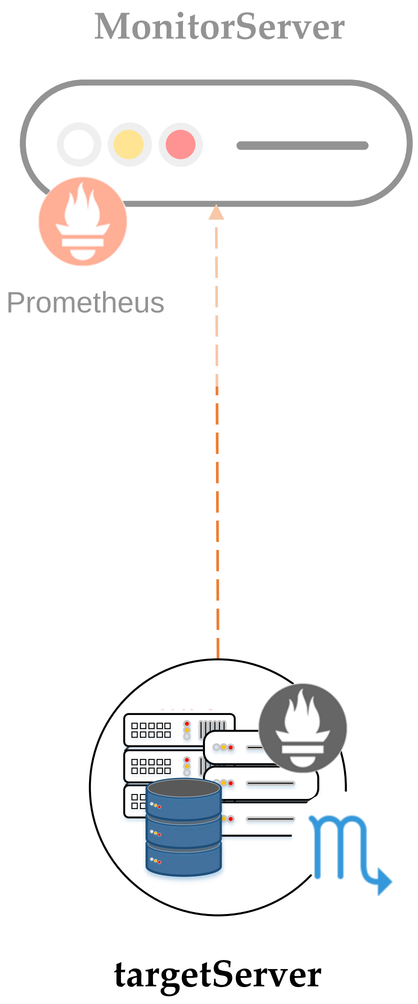
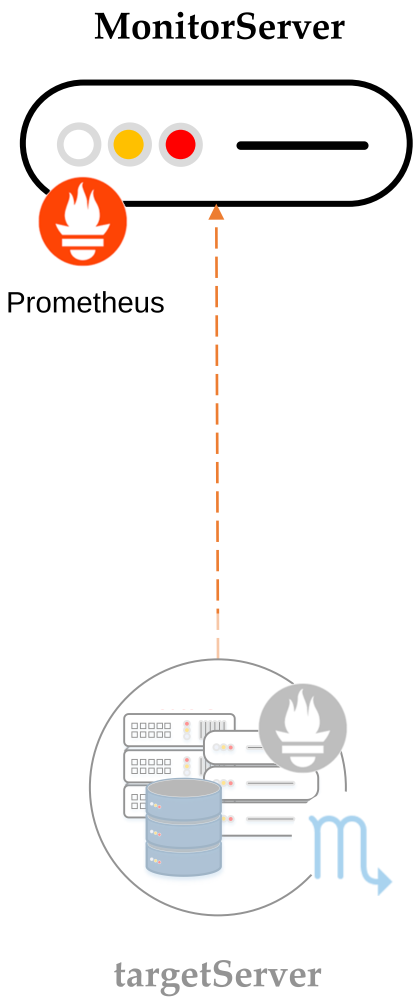



Prometheus configuration

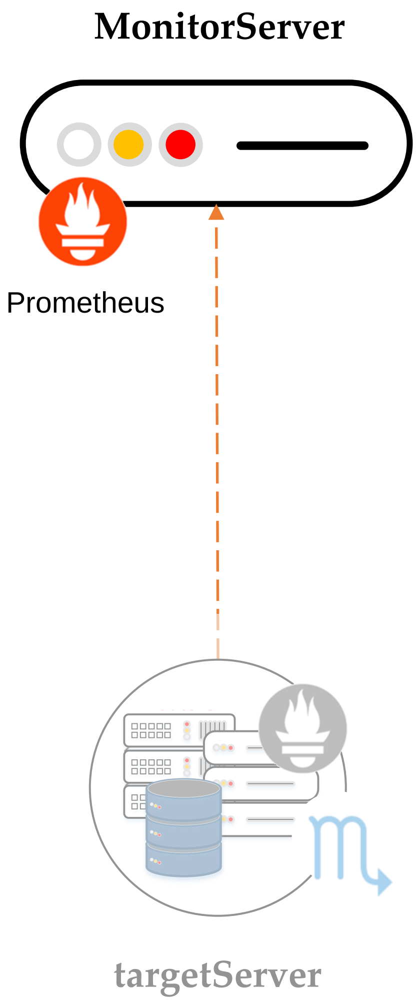
```
Terminal - MonitorServer

codedive@MonitorServer:~$
codedive@MonitorServer:~$ cd /usr/local/bin/prometheus/prometheus-2.37.2.linux-amd64/
codedive@MonitorServer:~$
codedive@MonitorServer:~$ vim prometheus.yml
```



Prometheus configuration

Terminal - vim prometheus.yml

```yaml
..........
..........
scrape_configs:
..........
..........
  - job_name: "nodes"
    # metrics definition
    scrape_interval: 5s
    static_configs:
           - targets: ["63.32.45.224:8081", "63.32.45.224:3903"]
             labels:
                      group: 'nodes'
```



Statistic Analysis

Insight over dataset

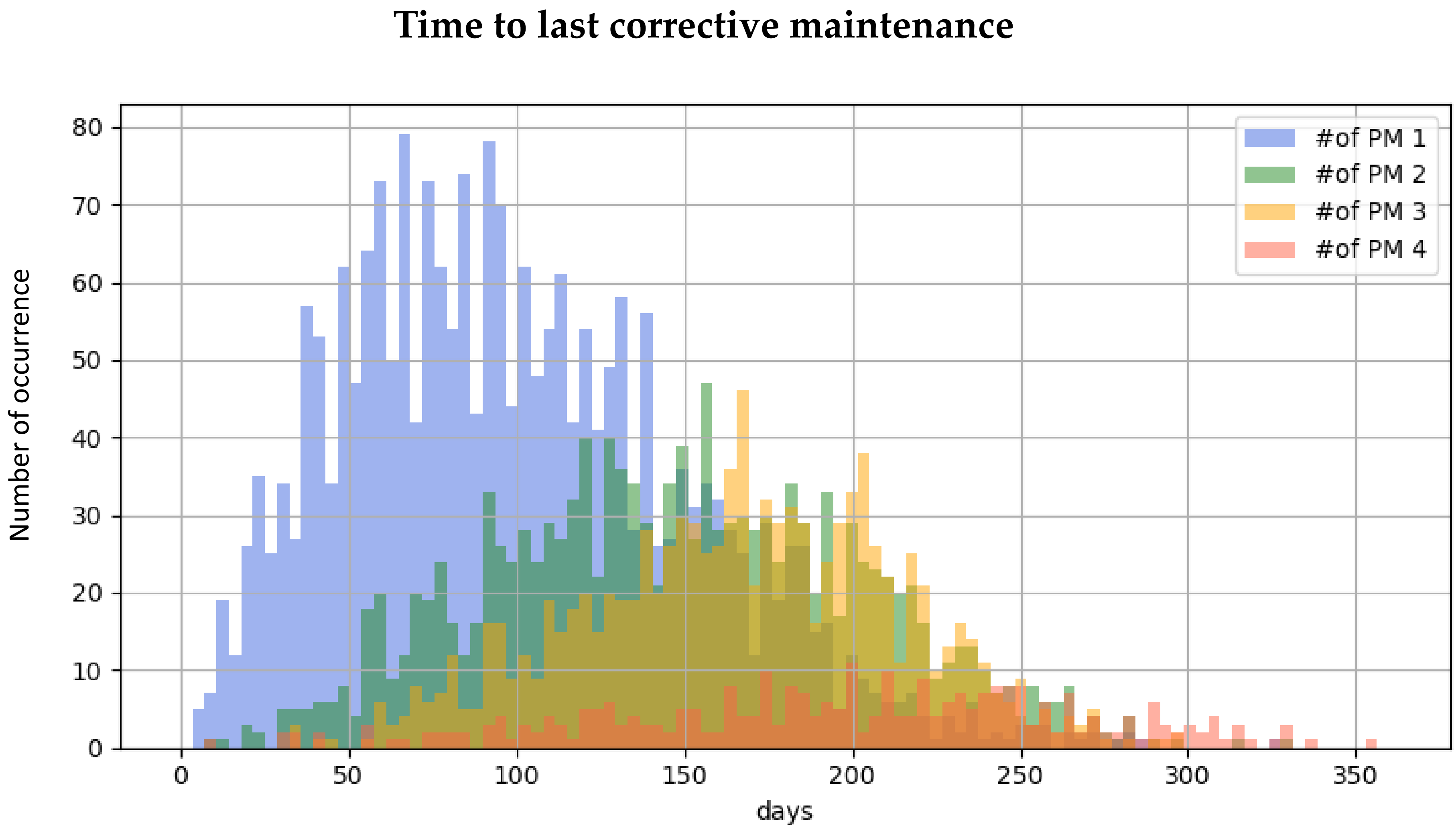
terminal

```
codedive@MonitorServer:~$ python
Python 3.9.5 (default, May 18,2021,14:42:02) (AMD64)::Anaconda, Inc.
Type "help", "copyright", "credits" or "license" for more information.
>>>
>>>
>>>
>>>
>>> import pandas as pd
>>> df = pd.read_csv('dataset/dataset.csv')
>>> print(df[:2000].describe(include='all').T)

                            count       mean        std   min    max
hardware alarms            2000.0     0.8970   0.854843   0.0    3.0
cpu errors                 2000.0     0.0480   0.246427   0.0    2.0
low voltage                2000.0     1.5595   1.155910   0.0    4.0
overheating alarm          2000.0     1.3440   1.249177   0.0    5.0
fan degradaded             2000.0     1.0665   1.044329   0.0    3.0
baseband processing fault  2000.0     0.2760   0.633265   0.0    3.0
synchronization failure    2000.0     0.0685   0.299754   0.0    2.0
low disk performace        2000.0     0.0730   0.318939   0.0    2.0
tlpm                       2000.0   122.0190  89.775478  10.0  359.0
tlcm                       2000.0   132.2450  62.102724   7.0  331.0
number of PM               2000.0     1.8815   0.942816   1.0    4.0
priority                   2000.0     2.5120   1.007156   1.0    4.0
other alarms               2000.0     0.2220   0.694231   0.0    4.0
failure                    2000.0     1.4625   1.180801   0.0    6.0
```

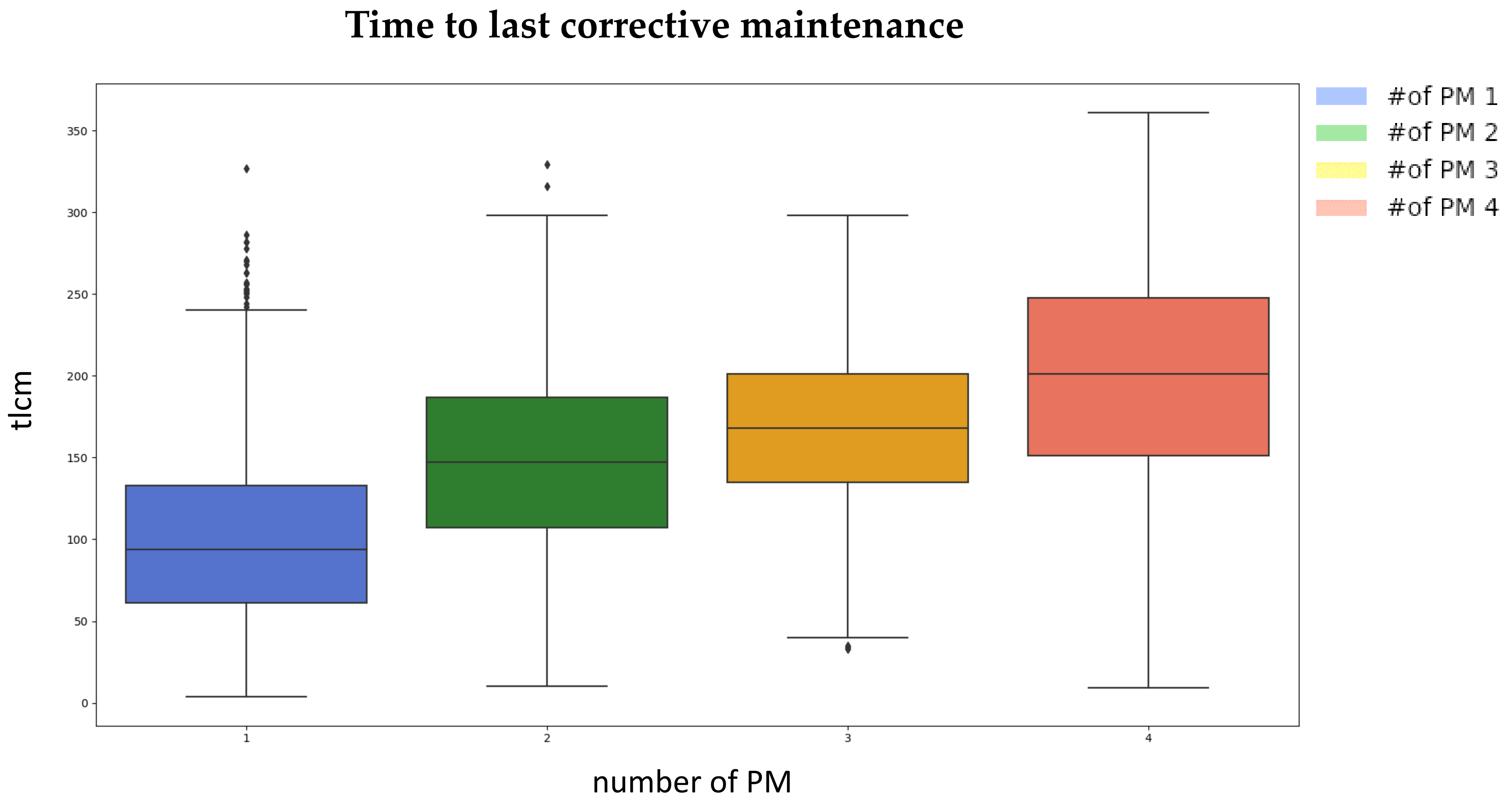
List of features

hardware alarms
cpu errors
low voltage
overheating alarm
fan degradaded
baseband processing fault
synchronization failure
low disk performace
tlpm
tlcm
number of PM
priority
other alarms
failure

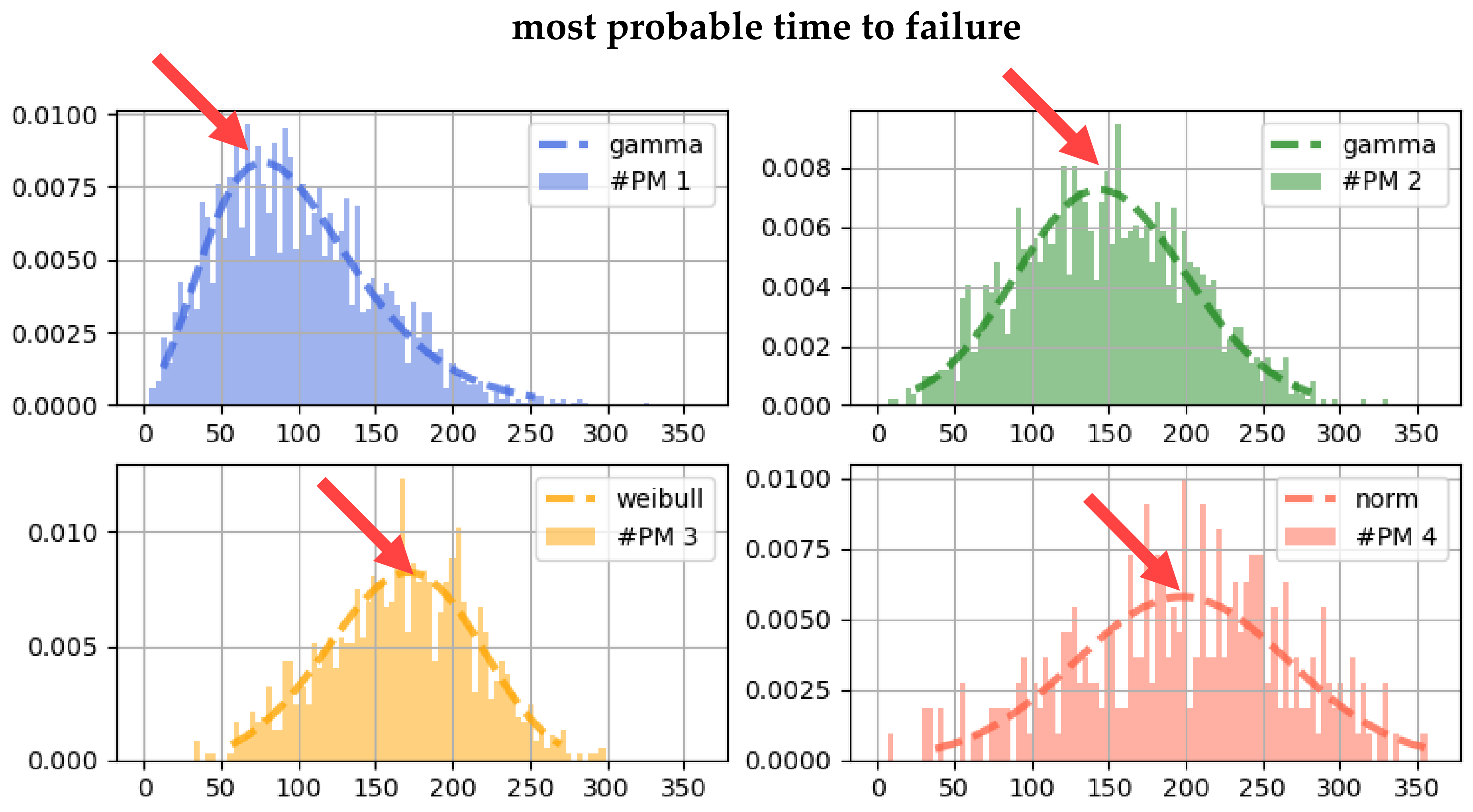
Histogram


Time to last corrective maintenance
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
days
Number of occurrence
#of PM 1
#of PM 2
#of PM 3
#of PM 4

Boxplot

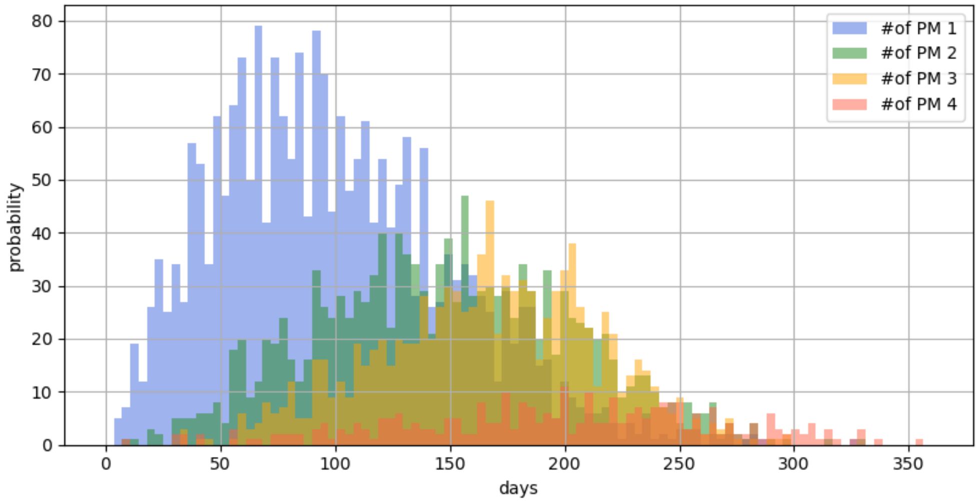

Time to last corrective maintenance
tlcm
0
50
100
150
200
250
300
350
1
2
3
4
number of PM
#of PM 1
#of PM 2
#of PM 3
#of PM 4

Fitting the Probability function



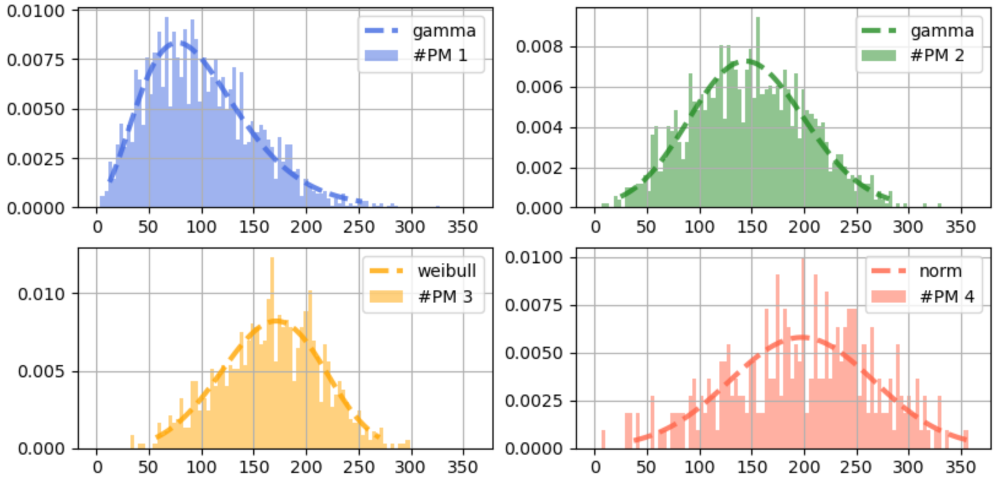
Insight over dataset

```
import numpy as np
import pandas as pd
from scipy.stats import gamma, weibull_min, norm
import matplotlib.pyplot as plt
from fitter import Fitter

df = pd.read_csv(‘dataset/dataset.csv')

plt.figure(1)
plt.hist(df.loc[df['number of PM'] == 1,'tlcm'], bins = 100,
            range=(0,360),alpha=0.5, label='#of PM 1', density=False,
            facecolor='royalblue’)

plt.hist(df.loc[df[‘number of PM'] == 2,'tlcm'], bins = 100,
            range=(0,360),alpha=0.5, label='#of PM 2', density=False,
            facecolor='forestgreen’)

plt.hist(df.loc[df['number of PM'] == 3,'tlcm'], bins = 100,
            range=(0,360),alpha=0.5, label='#of PM 3', density=False,
            facecolor='orange’)

plt.hist(df.loc[df['number of PM'] == 4,'tlcm'], bins = 100,
            range=(0,360),alpha=0.5, label='#of PM 4', density=False,
            facecolor='tomato')


plt.xlabel('days')
plt.ylabel('probability')
plt.grid()
plt.legend(loc='best’)
```



Insight over dataset

```python
# plot and fitting the pdf based on different #number of PMs
# ----------------------------------- PM = 1 -----------------------------------
plt.figure(2)
plt.subplot(2, 2, 1)
dataIn = df.loc[df['number of PM'] == 1,'tlcm']
f = Fitter(dataIn, distributions=['gamma', "weibull_min", "norm"])
f.fit()
print('parameter for #PM=1 are: {}'.format(f.get_best(method = 'sumsquare_error')))
bFitPara = f.get_best(method = 'sumsquare_error')
a = bFitPara['gamma']['a']
l = bFitPara['gamma']['loc']
s = bFitPara['gamma']['scale']

x = np.linspace(gamma.ppf(0.01, a, loc = l, scale = s), gamma.ppf(0.99, a, loc = l,
scale = s), 100)

plt.plot(x, gamma.pdf(x, a,loc = l, scale = s), '--', color='royalblue', lw=3,
             alpha=0.8, label='gamma’)

plt.hist(dataIn, bins = 100, range=(0,360), alpha=0.5, label='#PM 1', density=True,
             facecolor='royalblue’)

plt.grid()
plt.legend(loc='best’)


# plot for the remaining values of PM = {1,2,3,4} are almost same
```



Estimation of failures

Goal of estimation

Goal:

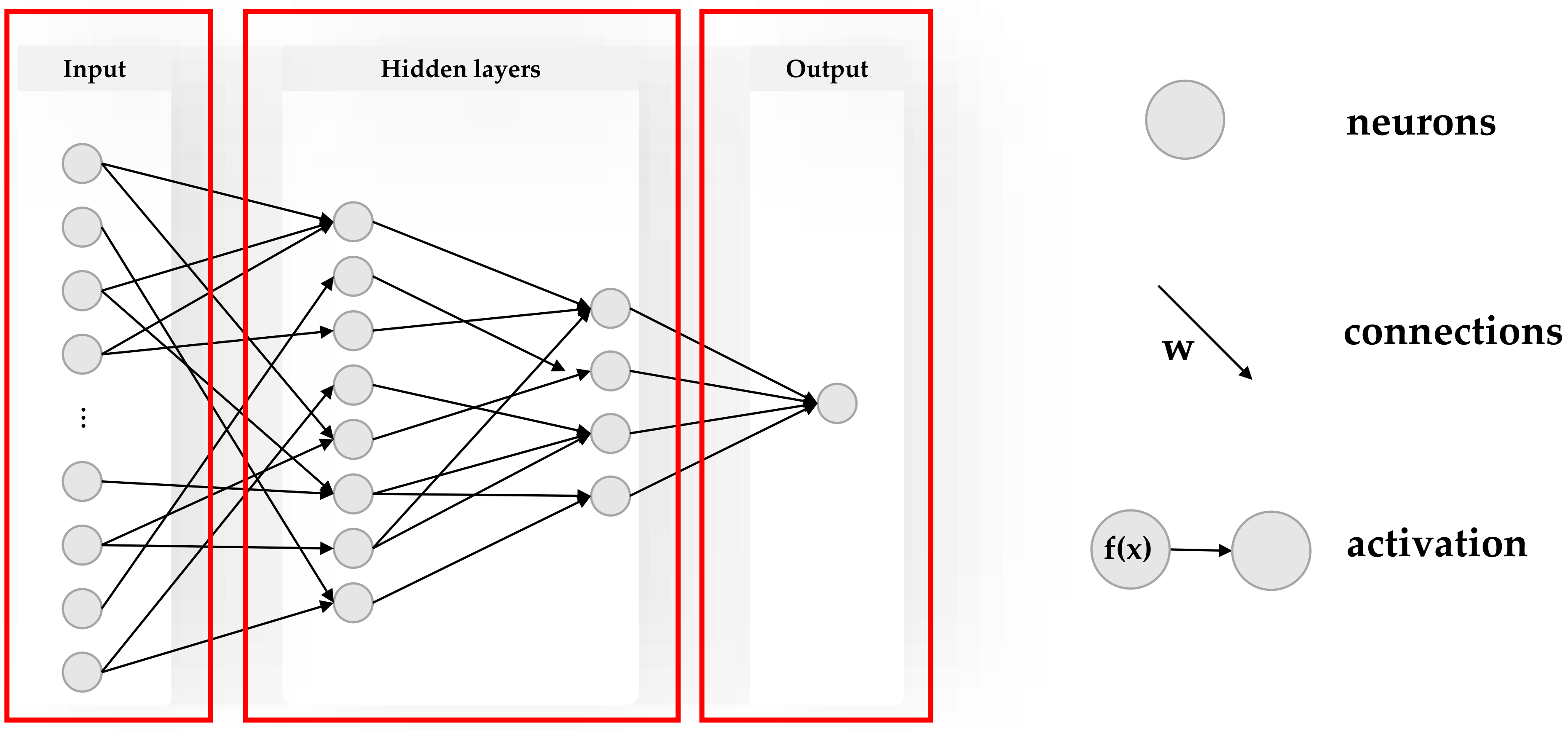
Anticipate the most probable failures

Methods:

Method 1: fit probability function over data

Method 2: use the neural network for estimation

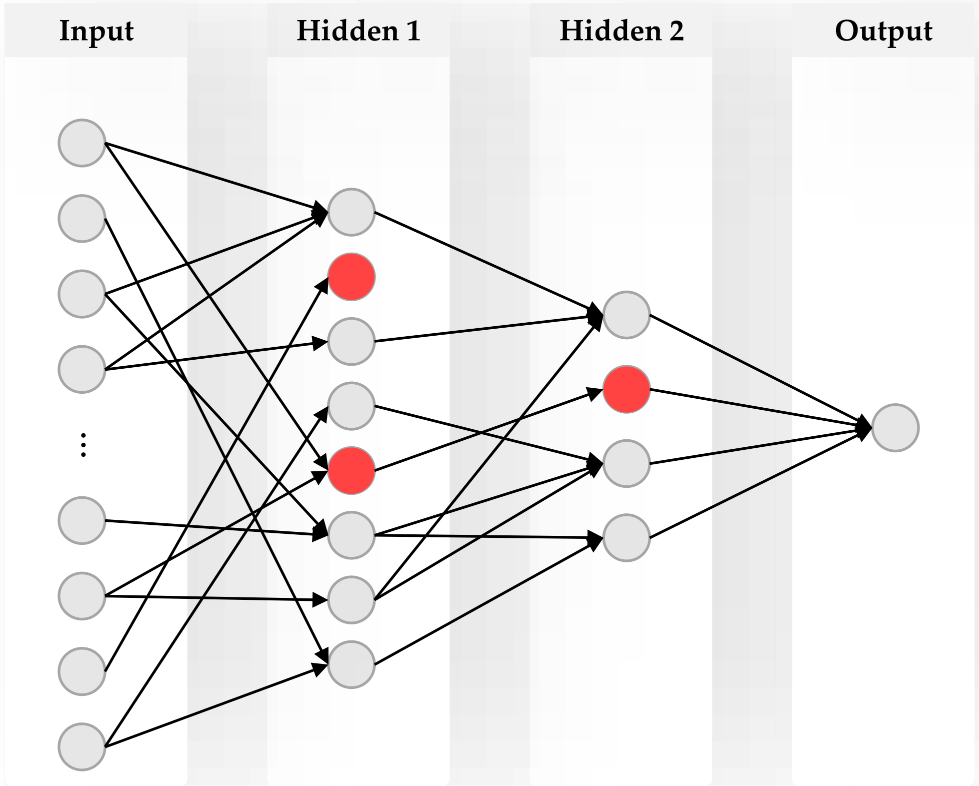
What is neural network?



Neural Network

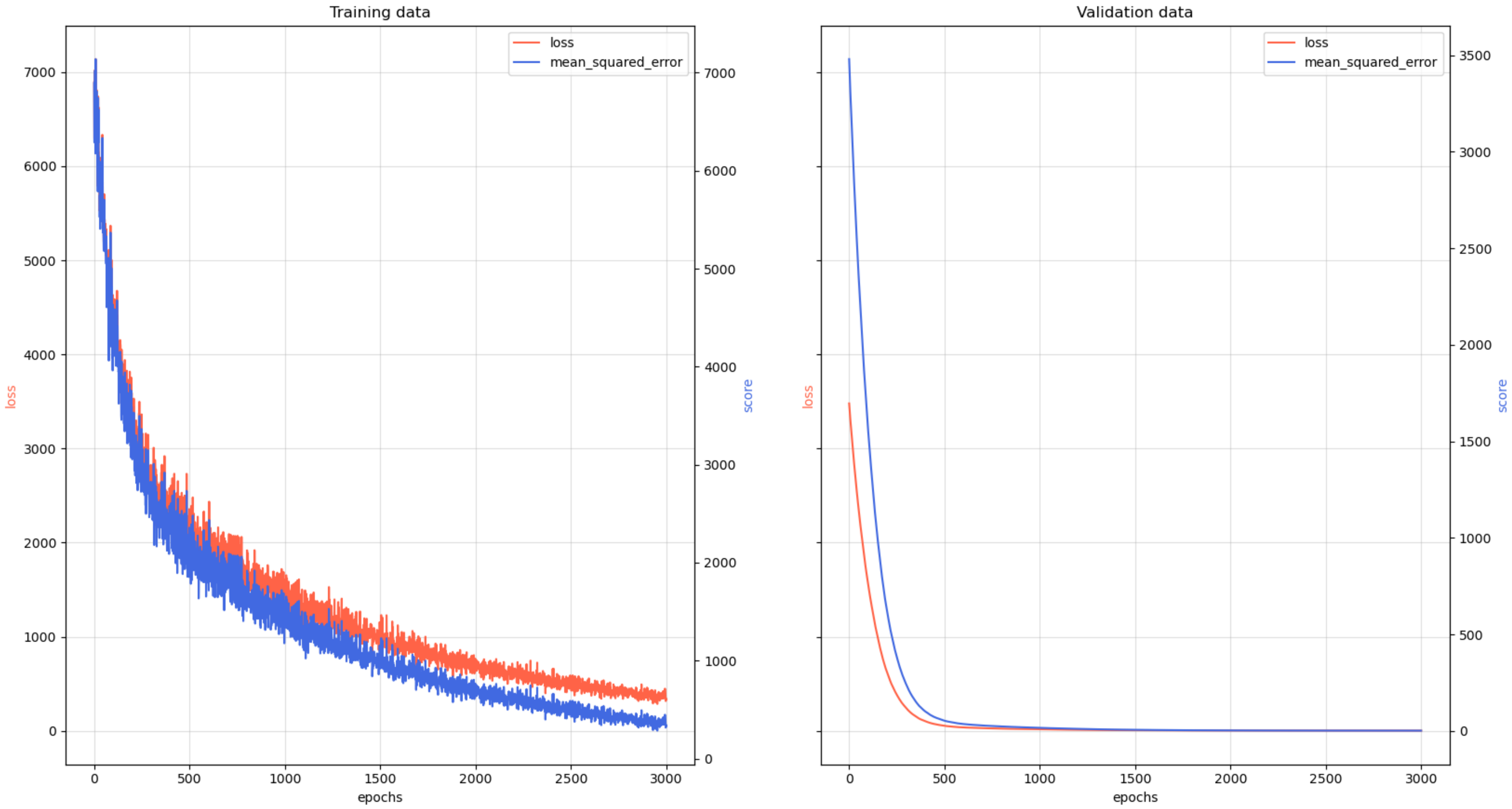
NN Model

```
import pandas as pd
from matplotlib import pyplot as plt
from tensorflow.keras import models, layers, metrics
import shap
import tensorflow as tf

tf.random.set_seed(5)

df = pd.read_csv('dataset/dataset.csv', index_col=None)

# create neural network model
model = models.Sequential()
model.add(layers.Dense(name="Hidden 1", input_dim=13, units=8, activation='linear'))
model.add(layers.Dropout(name="drop1", rate=0.15))
model.add(layers.Dense(name="Hidden 2", units=4, activation='linear'))
model.add(layers.Dropout(name="drop2", rate=0.15))
model.add(layers.Dense(name="Output", units=1, activation='linear'))

model.compile(optimizer='Adadelta', loss='mse',
             metrics=[tf.keras.metrics.MeanSquaredError()])

dataOut = df['failure']
dataIn  = df.drop(['failure'], axis=1)

x_training =  dataIn[0:1000].values
y_training = dataOut[0:1000].values

training = model.fit(x=x_training, y=y_training, batch_size=8, epochs=3000,
             shuffle=True, verbose=1, validation_split=0.3)
```



Neural Network

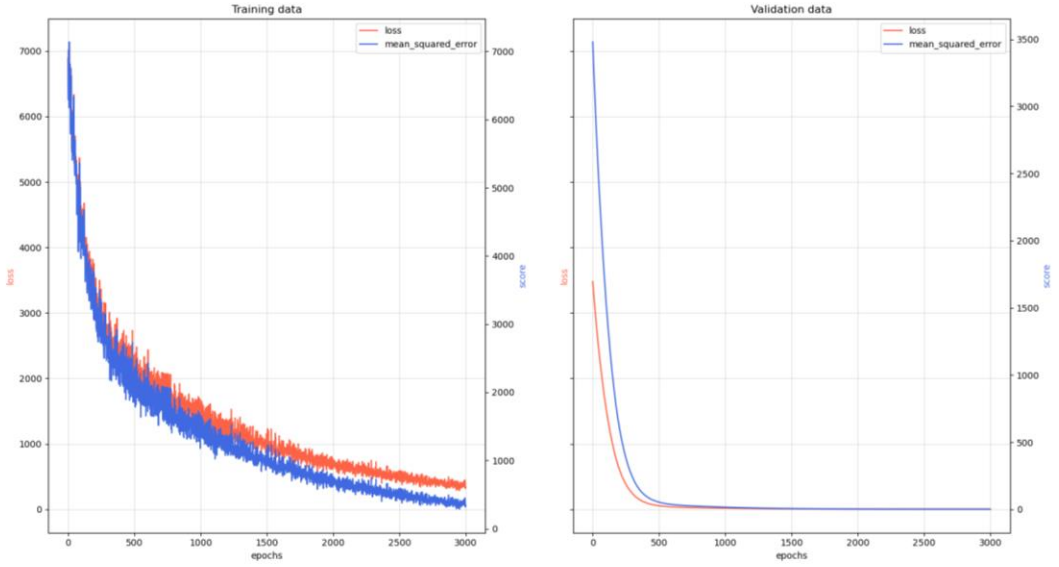
learning process vs. epochs



Neural Network

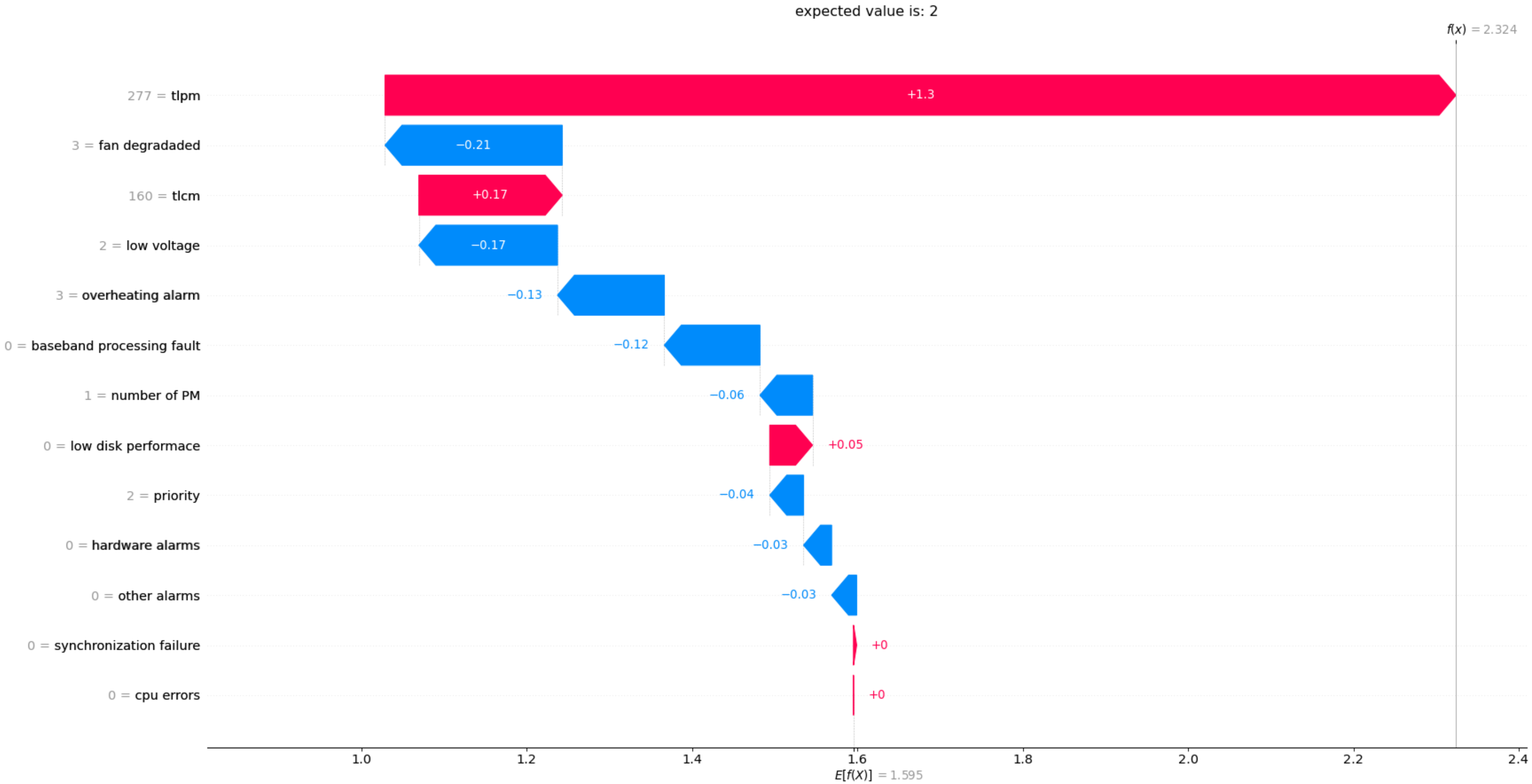
plots

```python
# plots for training and validation on dataset
fig, ax = plt.subplots(nrows=1, ncols=2, sharey=True)

plt.figure(1)
# training plot
ax[0].set(title="Training data")
ax11 = ax[0].twinx()
lns01 = ax[0].plot(training.history['loss'], color='tomato', label='loss')
ax[0].set_xlabel('epochs')
ax[0].set_ylabel('loss', color='tomato')
lns02 = ax11.plot(training.history[metric], label=metric, color='royalblue')
ax11.set_ylabel("score", color='royalblue')

lns = lns01+lns02
labs = [l.get_label() for l in lns]
ax[0].legend(lns, labs, loc='upper right')
ax[0].grid(alpha=0.4)

# validation plot
ax[1].set(title="Validation data")
ax22 = ax[1].twinx()
lns11 = ax[1].plot(training.history['val_loss'], color='tomato', label='loss')
ax[1].set_xlabel('epochs')
ax[1].set_ylabel('loss', color='tomato')
lns12 = ax22.plot(training.history['val_'+metric], label=metric, color='royalblue')
ax22.set_ylabel("score", color="royalblue")

lns = lns11+lns12
labs = [l.get_label() for l in lns]
ax[1].legend(lns, labs, loc='upper right')
ax[1].grid(alpha=0.4)

```



Neural Network

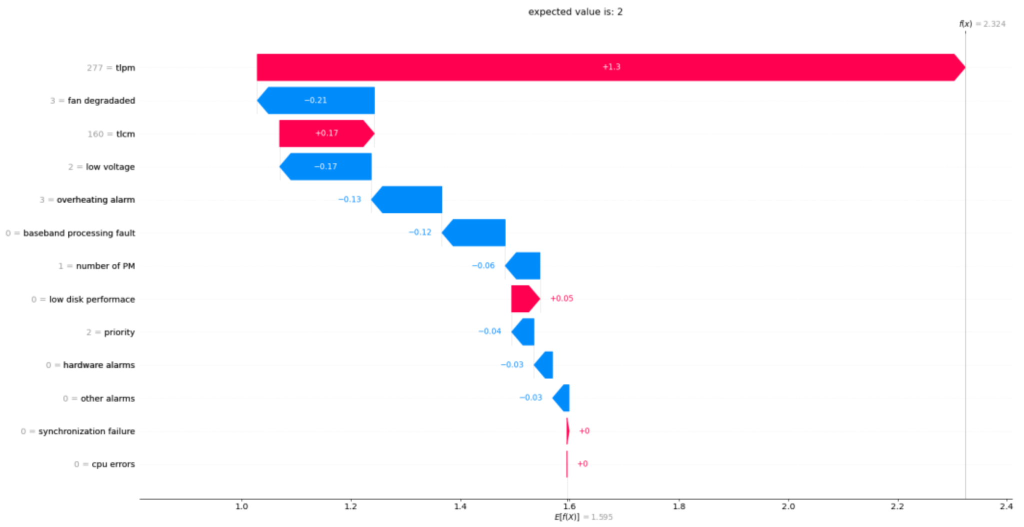
effect of each feature on estimated target



Neural Network

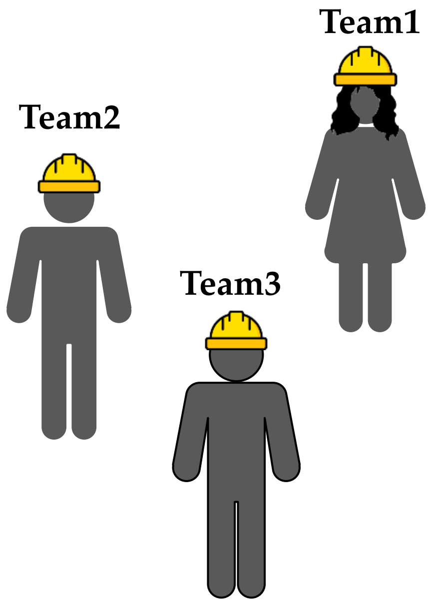
shap

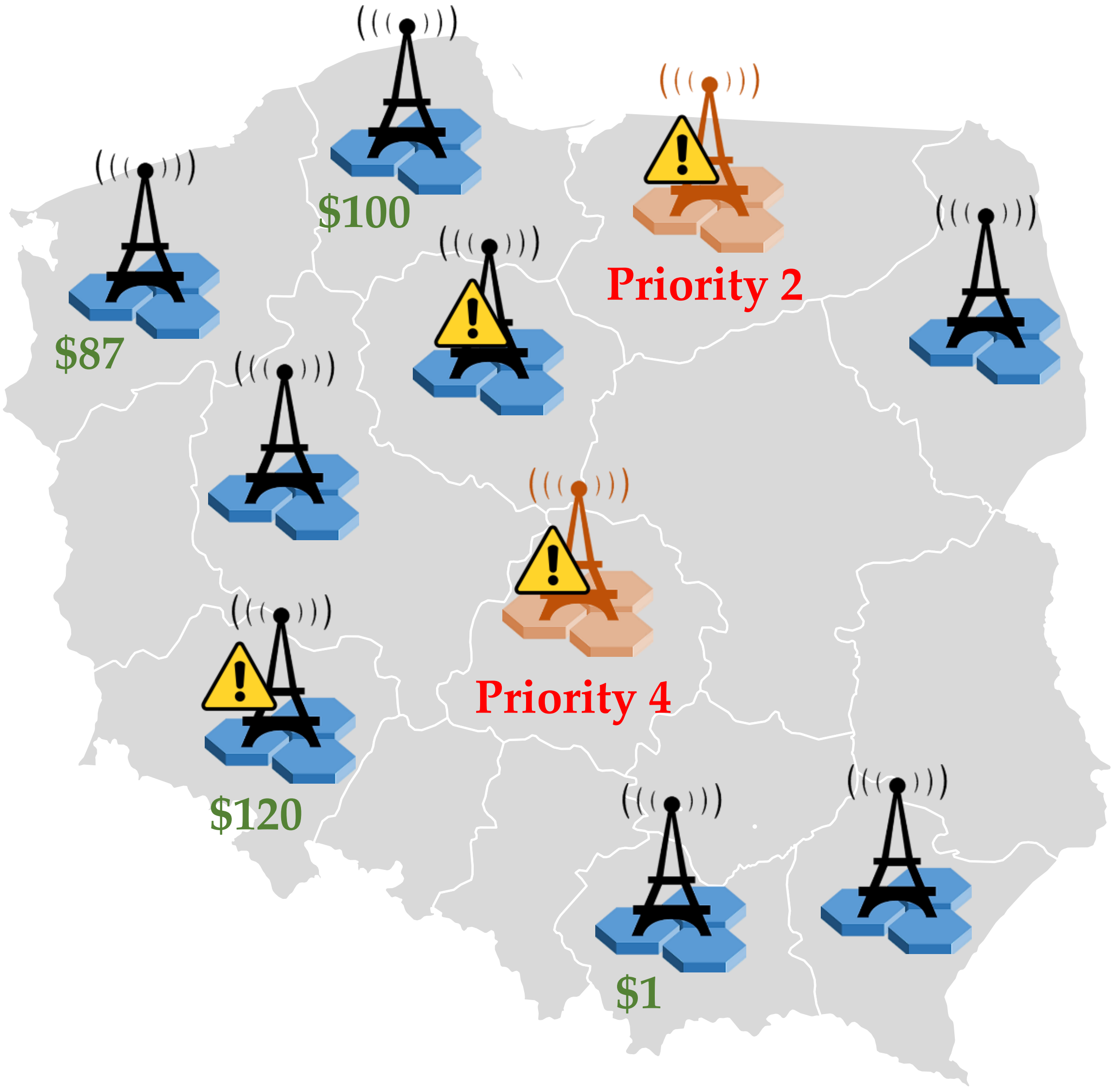
```python
# impact of feature to the value of target
dataInExplainer = dataIn[-1:].values
dataOutExpected = dataOut[-1:]

explainer = shap.Explainer(model, x_training)
shap_values = explainer(dataInExplainer)

values = shap_values.values[0]
base_values = shap_values.base_values[0][0]
datas = df[-1:].values[0]
columns = list(df.columns)[:-1] # exclude failure column

plt.figure(2, figsize=(10, 8), dpi=80)
exp = shap.Explanation(values, base_values, data=dataInExplainer[0],
                       feature_names=columns)
shap.plots.waterfall(exp, max_display=13, show=False)
plt.rcParams["font.size"] = "12"
plt.title('expected value is: {}'.format(dataOutExpected.values[0]))
plt.grid()
plt.show()
```



Modeling

Modeling





Modeling

Probable financial loss:

```
for each node:
    p = find probability of failure
    c = find income per day
    Ci = p * c
```

Probable non-financial loss:

```
for each node:
    p = find probability of failure
    m = rate the node based on its importance 0-100
    Pi = p * m
```

Modeling

Sets and Indices

I : Set of all available task, $i \in I$

M : Set of all available Workforces, $m \in M$

Parameters

c_i : Probable financial loss due to task i

p_i : Probable non-financial loss due to task i

T_m : Available time in hours for workforce m

a_{im} : time consumed by workforce m to complete task i

Variables

y_{im} : is equal to 1 if workforce m is assigned to task i

w_i : is equal to 1 if task i is selected to be performed

Cost function

$$Max\{\alpha_1 \times F_1 + \alpha_2 \times F_2\}$$

Where:

$$F_1 = \sum_{i \in I} c_i w_i$$ Cost function of financial loss

$$F_2 = \sum_{i \in I} p_i w_i$$ Cost function of non-financial loss

Constraints

$$w_i = \{0,1\} \quad \forall i \in I$$

$$y_{im} = \{0,1\} \quad \forall i \in I, m \in M$$

$$\sum_{m \in M} y_{im} = w_i \quad \forall i$$ assign only a task to a workforce

$$\max \sum_{i \in I} a_{im} y_{im} \le T_m \quad \forall m \in M$$ workforce time limitation

Modeling

```python
import pyomo.opt as po
import pyomo.environ as pe

I   = ['BTS01', 'BTS03', 'BTS04', 'BTS05', 'BTS08', 'BTS10']
M   = ['Team01', 'Team02', 'Team03']
Ci  = {'BTS01': 109, 'BTS03': 89, 'BTS04': 23, 'BTS05': 54, 'BTS08': 86, 'BTS10':
68}
Pi  = {'BTS01': 17, 'BTS03': 2, 'BTS04': 100, 'BTS05': 21, 'BTS08': 71, 'BTS10': 34}
Tm  = {'Team01': 2, 'Team02': 2, 'Team03': 3}

Aim = {
    ('BTS01', 'Team01'): 1, ('BTS01', 'Team02'): 3, ('BTS01', 'Team03'): 1.5,
    ('BTS03', 'Team01'): 2, ('BTS03', 'Team02'): 5, ('BTS03', 'Team03'): 0.5,
    ('BTS04', 'Team01'): 3, ('BTS04', 'Team02'): 4, ('BTS04', 'Team03'): 4,
    ('BTS05', 'Team01'): 1, ('BTS05', 'Team02'): 1, ('BTS05', 'Team03'): 5,
    ('BTS08', 'Team01'): 3, ('BTS08', 'Team02'): 9, ('BTS08', 'Team03'): 3,
    ('BTS10', 'Team01'): 4, ('BTS10', 'Team02'): 5, ('BTS10', 'Team03'): 1
}

# set solver and create model
solver = po.SolverFactory('glpk')
model = pe.ConcreteModel()

# Set & Indices definition
model.i = pe.Set(initialize=I)
model.m = pe.Set(initialize=M)

# Parameter Declaration
model.ci = pe.Param(model.i, initialize=Ci)
model.pi = pe.Param(model.i, initialize=Pi)
model.tm = pe.Param(model.m, initialize=Tm)
model.aim = pe.Param(model.i, model.m, initialize=Aim)
```

Sets and Indices

I : Set of all available skills, $i \in I$

M : Set of all available Workforces, $m \in M$

Parameters

c_i : Probable financial loss due to task i

p_i : Probable non-financial loss due to task i

T_m : Available time in hours for workforce m

a_{im} : time consumed by workforce m to complete task i

Modeling

```python
# Variable declaration
model.yim = pe.Var(model.i, model.m, domain=pe.Binary)
model.wi = pe.Var(model.i, domain=pe.Binary)

# cost function
def costfunc(model):
    alphaC = 0.7; alphaP = 0.3
    fC = sum(model.ci[i] * model.wi[i] for i in model.i)
    fP = sum(model.pi[i] * model.wi[i] for i in model.i)
    return alphaC * fC + alphaP * fP

model.obj = pe.Objective(rule = costfunc, sense = pe.maximize)

# contstraint definition
def ruleC1(model, i):
    return sum(model.yim[i,m] for m in model.m) == model.wi[i]

model.C1 = pe.Constraint(model.i, rule=ruleC1)

def ruleC2(model, m):
    return sum(model.aim[i,m] * model.yim[i,m] for i in model.i) <= model.tm[m]

model.C2 = pe.Constraint(model.m, rule=ruleC2)
# solve the model
solver.solve(model)

# print outout of the model
model.pprint()
```

Variables

y_{im} : is equal to 1 if workforce m is assigned to task i

w_i : is equal to 1 if task i is selected to be performed

Cost function

$$Max\{\alpha_1 \times F_1 + \alpha_2 \times F_2\}$$

Where:

$$F_1 = \sum_{i \in I} c_i w_i$$ Cost function of financial loss

$$F_2 = \sum_{i \in I} p_i w_i$$ Cost function of non-financial loss

Constraints

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$$\sum_{m \in M} y_{im} = w_i \quad \forall i$$ assign only a task to a workforce

$$\max \sum_{i \in I} a_{im} y_{im} \leq T_m \quad \forall m \in M$$ workforce time limitation

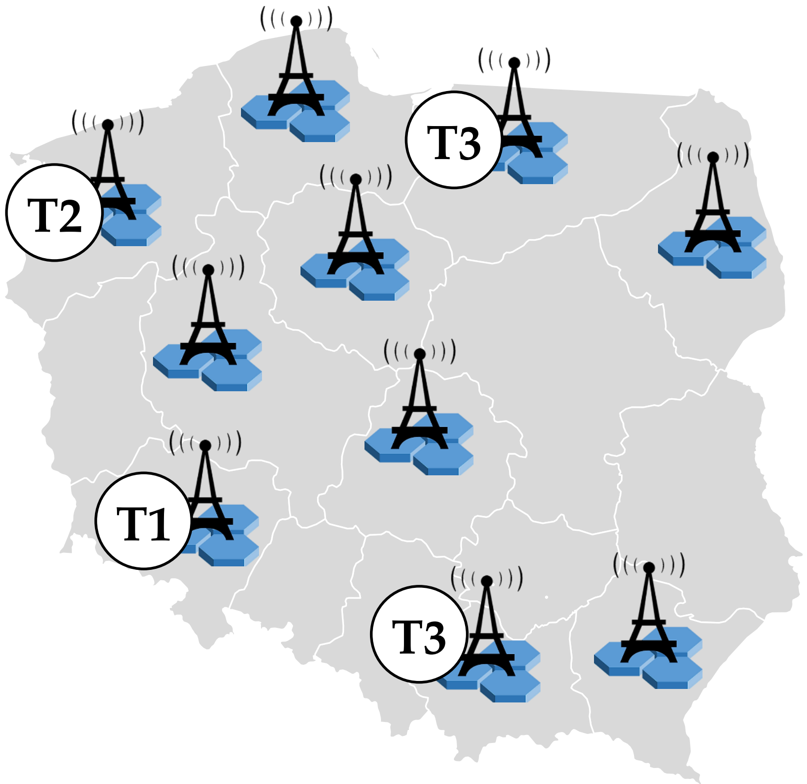
Modeling

terminal

```
codedive@MonitorServer:~$ python ORMModel.py
...

2 Var Declarations
    wi : Size=6, Index=i
        Key    : Lower : Value : Upper : Fixed : Stale : Domain
        BTS01 :     0 :   1.0 :     1 : False : False : Binary
        BTS03 :     0 :   1.0 :     1 : False : False : Binary
        BTS04 :     0 :   0.0 :     1 : False : False : Binary
        BTS05 :     0 :   1.0 :     1 : False : False : Binary
        BTS08 :     0 :   0.0 :     1 : False : False : Binary
        BTS10 :     0 :   1.0 :     1 : False : False : Binary

    yim : Size=18, Index=yim_index
        Key                    : Lower : Value : Upper : Fixed : Stale : Domain
        ('BTS01', 'Team01') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS01', 'Team02') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS01', 'Team03') :     0 :   1.0 :     1 : False : False : Binary
        ('BTS03', 'Team01') :     0 :   1.0 :     1 : False : False : Binary
        ('BTS03', 'Team02') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS03', 'Team03') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS04', 'Team01') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS04', 'Team02') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS04', 'Team03') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS05', 'Team01') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS05', 'Team02') :     0 :   1.0 :     1 : False : False : Binary
        ('BTS05', 'Team03') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS08', 'Team01') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS08', 'Team02') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS08', 'Team03') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS10', 'Team01') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS10', 'Team02') :     0 :   0.0 :     1 : False : False : Binary
        ('BTS10', 'Team03') :     0 :   1.0 :     1 : False : False : Binary
```



Thank you