National College of Ireland

Configuration Manual

MSc Research Project
Cloud Computing

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MSc Project Submission Sheet

School of Computing

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Lecturer:	Ahmed Makki
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Configuration Manual

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1 Introduction

This configuration document is step-by-step tutorial needed to set up and deploy the research project of resource management optimization in Kubernetes clusters. The project involves deploying an adaptive scheduler and integrating threshold-based predictive autoscaling models with Alibaba Cluster Trace data.

2 Setup Environment

Open PowerShell as a Admin:
Run below command:
minikube start --driver=docker --cpus=4 --memory=8192

Install Kubernetes and check if Kubernetes is running or not:
kubectl get nodes

Run below command:
kubectl version –client

Install Helm using Chocolatey:

```
PS C:\Users\hrish\AlibabaClusterTrace> Set-ExecutionPolicy Bypass -Scope Process -Force; `
>> [System.Net.ServicePointManager]::SecurityProtocol = `
>> [System.Net.ServicePointManager]::SecurityProtocol -bor 3072; `
>> iex ((New-Object System.Net.WebClient).DownloadString('https://chocolatey.org/install.ps1'))
>>
WARNING: 'choco' was found at 'C:\ProgramData\chocolatey\bin\choco.exe'.
WARNING: An existing Chocolatey installation was detected. Installation will not continue. This script will not
overwrite existing installations.
If there is no Chocolatey installation at 'C:\ProgramData\chocolatey', delete the folder and attempt the installation
again.

Please use choco upgrade chocolatey to handle upgrades of Chocolatey itself.
If the existing installation is not functional or a prior installation did not complete, follow these steps:
 - Backup the files at the path listed above so you can restore your previous installation if needed.
 - Remove the existing installation manually.
 - Rerun this installation script.
 - Reinstall any packages previously installed, if needed (refer to the lib folder in the backup).

Once installation is completed, the backup folder is no longer needed and can be deleted.
```

choco install kubernetes-helm

Check Installation version:
helm version

For Monitoring install Prometheus + Grafana and add Helm chart:

```
PS C:\Users\hrish\AlibabaClusterTrace> helm repo add prometheus-community https://prometheus-community.github.io/helm-charts
>> helm repo update
>>
"prometheus-community" already exists with the same configuration, skipping
Hang tight while we grab the latest from your chart repositories...
...Successfully got an update from the "prometheus-community" chart repository
Update Complete. ⎈Happy Helming!⎈
```

Installing into Kubernetes:

```
PS C:\Users\hrish\AlibabaClusterTrace> helm install prometheus prometheus-community/kube-prometheus-stack
>>
NAME: prometheus
LAST DEPLOYED: Sat Aug  9 21:46:41 2025
NAMESPACE: default
STATUS: deployed
REVISION: 1
NOTES:
kube-prometheus-stack has been installed. Check its status by running:
  kubectl --namespace default get pods -l "release=prometheus"

Get Grafana 'admin' user password by running:

  kubectl --namespace default get secrets prometheus-grafana -o jsonpath="{.data.admin-password}" | base64 -d ; echo

Access Grafana local instance:

  export POD_NAME=$(kubectl --namespace default get pod -l "app.kubernetes.io/name=grafana,app.kubernetes.io/instance=prometheus" -oname)
  kubectl --namespace default port-forward $POD_NAME 3000

Visit https://github.com/prometheus-operator/kube-prometheus for instructions on how to create & configure Alertmanager and Prometheus instances using the Operator.
```

Installing Metrics Server:

```
PS C:\Users\hrish\AlibabaClusterTrace> kubectl apply -f https://github.com/kubernetes-sigs/metrics-server/releases/latest/download/components.yaml
>>
serviceaccount/metrics-server unchanged
clusterrole.rbac.authorization.k8s.io/system:aggregated-metrics-reader unchanged
clusterrole.rbac.authorization.k8s.io/system:metrics-server unchanged
rolebinding.rbac.authorization.k8s.io/metrics-server-auth-reader unchanged
clusterrolebinding.rbac.authorization.k8s.io/metrics-server:system:auth-delegator unchanged
clusterrolebinding.rbac.authorization.k8s.io/system:metrics-server unchanged
service/metrics-server unchanged
deployment.apps/metrics-server configured
apiservice.apiregistration.k8s.io/v1beta1.metrics.k8s.io unchanged
PS C:\Users\hrish\AlibabaClusterTrace> kubectl top nodes
>>
NAME       CPU(cores)   CPU%   MEMORY(bytes)   MEMORY%
minikube   1721m        43%    3254Mi          40%
```

After 1 minutes, run to check:
kubectl top nodes

3 Load the Dataset

Install Python and pip

Install Jupyter Notebook and libraries
pip install jupyter pandas numpy matplotlib seaborn statsmodels pmdarima scikit-learn

Place Alibaba dataset in folder

Run the below code to create preprocessed csv file:

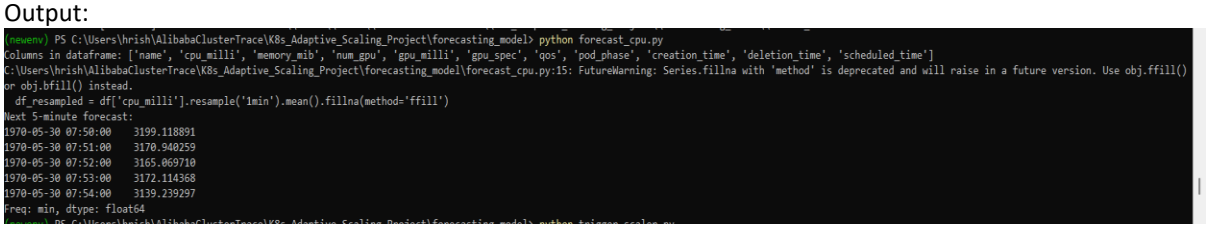
```
import pandas as pd

df = pd.read_csv("../dataset/openb_pod_list_cpu037.csv")
print("Data loaded")

df['timestamp'] = pd.to_datetime(df['timestamp'])
df.set_index('timestamp', inplace=True)

df = df.resample("1min").mean().interpolate()

print(df.head())

df.to_csv("../dataset/preprocessed_data.csv")
print(" Preprocessing complete. Data saved as preprocessed_data.csv")
```

4 Forecasting Model

Step 1:
Create a python code for cpu usage in next 5 minutes and run forecast_cpu.py :

```
import pandas as pd
from statsmodels.tsa.holtwinters import ExponentialSmoothing

df = pd.read_csv(
    r"C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\dataset\preprocessed_data.csv",
    index_col='timestamp', parse_dates=True
)

print("Columns in dataframe:", df.columns.tolist())

#  timestamp index sorting
df = df.sort_index()


df_resampled = df['cpu_milli'].resample('1min').mean().fillna(method='ffill')


model = ExponentialSmoothing(df_resampled, trend="add", seasonal="add", seasonal_periods=60)
fit = model.fit()

forecast = fit.forecast(5)
print("Next 5-minute forecast:")
print(forecast)


forecast.to_csv(r"C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\forecasting_model\latest_forecast.csv")
```

Output:



Step 2:
Create trigger_scaler.py for threshold CPU usage 75% and run it:

```
import pandas as pd
import subprocess


df = pd.read_csv("latest_forecast.csv", index_col=0)

# Threshold for CPU usage  75%
THRESHOLD = 0.75


avg_cpu = df.iloc[:, 0].mean()

print(f"Forecasted average CPU: {avg_cpu:.2f}")


if avg_cpu > THRESHOLD:
    print(" High forecast detected. Scaling up deployment...")
    subprocess.run(["kubectl", "scale", "deployment", "hello-minikube", "--replicas=5"])
else:
    print(" CPU within limits. No scaling action taken.")
```

```
error: no objects passed to scale
(newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\forecasting_model> kubectl get deployments
>>
NAME                              READY   UP-TO-DATE   AVAILABLE   AGE
hello-minikube                    1/1     1            1           10d
prometheus-grafana                1/1     1            1           3d18h
prometheus-kube-prometheus-operator   1/1     1            1           3d18h
prometheus-kube-state-metrics     1/1     1            1           3d18h
prometheus2-grafana               1/1     1            1           20h
prometheus2-kube-prometheu-operator   1/1     1            1           20h
prometheus2-kube-state-metrics    1/1     1            1           20h
(newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\forecasting_model> python trigger_scaler.py
Forecasted average CPU: 3169.30
⚠ High forecast detected. Scaling up deployment...
deployment.apps/hello-minikube scaled
```

Step3:
Install Pip Kubernetes:
Pip install Kubernetes

Create scheduler.py to assign incoming node with predicted load to implement adaptive scheduler and run it:

```python
def score_nodes(pod_name, forecast):

    config.load_kube_config()

    v1 = client.CoreV1Api()

    nodes = v1.list_node().items

    scores = {}

    for node in nodes:
        node_name = node.metadata.name

        alloc_cpu = node.status.allocatable.get('cpu')
        if alloc_cpu is None:
            alloc_cpu = 0
        else:
            alloc_cpu = int(alloc_cpu)


        used_cpu = 1

        #  forecast CPU load for this node (simulate as 0.5)
        future_util = forecast.get(node_name, 0.5)

        # Score = free CPU minus forecasted usage
        score = alloc_cpu - used_cpu - future_util
        scores[node_name] = score

    # Pick node with max score (most available capacity)
    best_node = max(scores, key=scores.get)
    print(f"Best node to schedule pod {pod_name}: {best_node}")
    return best_node

if __name__ == "__main__":

    test_forecast = {
        "minikube": 0.3,
    }
    score_nodes("test-pod", test_forecast)
```

```
(newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\custom_scheduler> python scheduler.py
Best node to schedule pod example-pod: minikube
```

Step4:
Run below two command in powershell:
kubectl get svc prometheus-operated -n default

```
(newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\custom_scheduler> kubectl get svc prometheus-operated -n default
>>
NAME                  TYPE        CLUSTER-IP   EXTERNAL-IP   PORT(S)    AGE
prometheus-operated   ClusterIP   None         <none>        9090/TCP   3d18h
(newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\custom_scheduler> kubectl port-forward svc/prometheus-operated 9090:9090 -n default
>>
Forwarding from 127.0.0.1:9090 -> 9090
Forwarding from [::1]:9090 -> 9090
```

Run above snapshot command in another powershell and keep it open to get live cluster metrics from Prometheus.:

Create and run prometheus_query.py:

```python
from prometheus_api_client import PrometheusConnect
import datetime

def get_node_cpu_usage(prom_url='http://localhost:9090'):
    prom = PrometheusConnect(url=prom_url, disable_ssl=True)

    query = 'avg(rate(node_cpu_seconds_total{mode!="idle"}[5m])) by (instance)'

    end_time = datetime.datetime.now()
    start_time = end_time - datetime.timedelta(minutes=5)

    result = prom.custom_query_range(
        query=query,
        start_time=start_time,
        end_time=end_time,
        step='60s',
    )

    cpu_usage = {}
    for metric_data in result:
        instance = metric_data['metric']['instance']
        values = metric_data['values']
        avg_val = sum(float(v[1]) for v in values) / len(values)
        cpu_usage[instance] = avg_val

    return cpu_usage

if __name__ == "__main__":
    usage = get_node_cpu_usage()
    for node, val in usage.items():
        print(f"Node: {node} CPU usage: {val:.2f} cores")
```

```
newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\custom_scheduler> python prometheus_query.py
ode: 192.168.49.2:9100 CPU usage: 0.01 cores
```

Step5:
Create and run node_info.py that retrieves CPU, memory from Kubernetes API:

```python
from kubernetes import client, config

def get_nodes_cpu():
    config.load_kube_config()  # loads ~/.kube/config for cluster connection
    v1 = client.CoreV1Api()
    nodes = v1.list_node().items

    node_cpu_info = {}
    for node in nodes:
        name = node.metadata.name
        cpu_alloc = node.status.allocatable['cpu']
        # CPU allocatable is string like '4' or '4000m' (m=millicores)
        # convert to float cores:
        if cpu_alloc.endswith('m'):
            cpu_alloc = float(cpu_alloc[:-1]) / 1000
        else:
            cpu_alloc = float(cpu_alloc)
        node_cpu_info[name] = cpu_alloc
    return node_cpu_info

if __name__ == "__main__":
    cpu_info = get_nodes_cpu()
    for node, cpu in cpu_info.items():
        print(f"{node}: {cpu} CPU cores allocatable")
```

```
(newenv) PS C:\Users\hrish\AlibabaClusterTrace\K8s_Adaptive_Scaling_Project\custom_scheduler> python node_info.py
minikube: 4.0 CPU cores allocatable
```

Step6:
Create and run app.yaml:

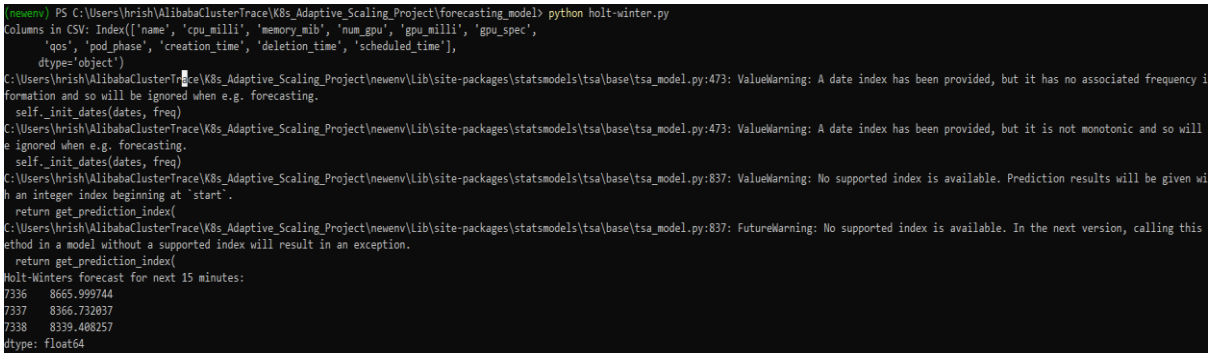
```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: app
spec:
  replicas: 1
  selector:
    matchLabels:
      app: test-api
  template:
    metadata:
      labels:
        app: test-api
    spec:
      containers:
      - name: test-api
        image: nginxdemos/hello
        ports:
        - containerPort: 80
        resources:
          requests:
            cpu: "100m"
          limits:
            cpu: "500m"
```

Step7 :
Install and Load test using K6:
choco install k6

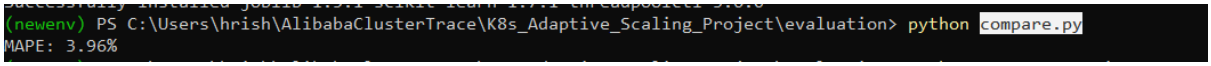
Create and run load_test:
k6 run load_test.js

Step8:
Create and run Holt_Winter.py to plot:

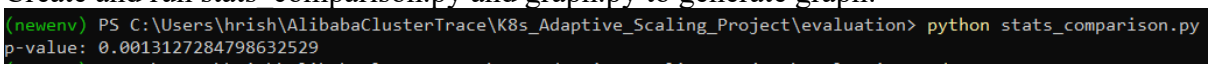
```
import matplotlib.pyplot as plt


df = pd.read_csv("../dataset/preprocessed_data.csv", parse_dates=['timestamp'])
df = df.sort_values('timestamp')
df.set_index('timestamp', inplace=True)

print("Columns in CSV:", df.columns)


cpu_daily = df['cpu_milli'].resample('D').mean()  # resample daily, take mean CPU

cpu_daily = cpu_daily.interpolate(method='time')


print(f"Data length after resample: {len(cpu_daily)}")


seasonal_periods = 7

model = ExponentialSmoothing(cpu_daily, trend='add', seasonal='add', seasonal_periods=seasonal_periods)
fit = model.fit()


forecast = fit.forecast(3)

print("Holt-Winters forecast for next 3 days:")
print(forecast)

# Plotting last 30 days + forecast
plt.figure(figsize=(10,6))
plt.plot(cpu_daily[-30:], label='Historical Daily CPU Usage')
plt.plot(forecast.index, forecast.values, label='Forecast', marker='o')
plt.xlabel('Date')
plt.ylabel('CPU Milli')
plt.title('CPU Usage Holt-Winters Forecast')
plt.legend()
plt.grid(True)
plt.show()
```



Step9:
Create and run compare.py to calculate MAPE:



Step10:
Create and run stats_comparison.py and graph.py to generate graph:



References

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Minikube. (2025). Minikube. [Online]. Available*: https://minikube.sigs.k8s.io.* [Accessed: 10- Aug- 2025].
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