An Evaluation of Data Center HVAC Environmental Monitoring Solution: Lightweight and Open Source

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# ABSTARCT

This paper examines the use of lightweight and open-source software for tracking environmental parameters such as temperature, humidity, and airflow within data canter HVAC (Heating, Ventilation, and Air Conditioning) systems. The study implements Prometheus with Grafana on a virtual machine running Ubuntu 24.04 and compares their performance. To test the tools’ efficacy, custom Python-based exporters were simulated sensor data that refreshed every 5 seconds. As noted in the results section, despite needing extra notification setup precision for alerting functions, Prometheus and Grafana displayed superb modularity alongside excellent resource-efficient dashboards within low overhead environments. The analysis supports consideration of these tools for monitoring system reliability and mitigating risks of HVAC failures in data centre’s while outlining prospective adjustments.

## Index Terms

HVAC monitoring, open-source tools, Prometheus, Grafana, Zabbix, data center uptime, environmental sensors, ASHRAE standards.

# Introduction

Data centers are critical components of the contemporary digital ecosystem, needing near-constant uptime to power important functions. HVAC systems are central to equipment overheating and degradation preventative repairs by controlling temperature, humidity, and airflow [1]. Thousands of dollars per hour can be lost due to organizational downtimes as a result of HVAC malfunctions [2]. This paper examines Prometheus with Grafana as open-source lightweight monitoring tools which could solve these issues. It integrates theoretical analyses on industry norms (e.g., ASHRAE guidelines) with practical implementation to evaluate setup difficulty, resource usage, dashboard quality, flexibility and alerting tools for systems responsive design. The ultimate aim is enabling data canter operators a framework that is easier to expand and more cost-effective to monitor.

# Theoretical Background

For data centres, operational environmental attributes like temperature (°C), humidity (%RH), and airflow (CFM) are important. ASHRAE indicates that the optimal relative humidity is between 20-60% and temperatures ranging from 18-27 °C for averting equipment malfunction [2]. Poorly controlled HVAC systems can lead to significant amounts of downtime, with some estimating costs in the thousands per hour [3]. We aim to examine how monitoring tools using open-source platforms can provide cost-effective solutions while still implementing effective preventative safeguards and fail-safety mechanisms to avert system failures.

# Tool Selection and Evaluation Criteria

Prometheus, along with Grafana for visualization, was selected after considering community support and existing documentation. As previously discussed, Prometheus provides a modular approach which enables the use of supplementary tools such as Grafana for visualization. Evaluation criteria include:

* **Setup Difficulty**: Ease of installation and configuration.
* **Resource Usage**: Memory and CPU consumption.
* **Dashboard Quality**: Visualization clarity and customization.
* **Flexibility**: Adaptability to different monitoring needs.
* **Alerting**: Effectiveness of notification systems.

These criteria are consistent with the requirements for lightweight, easily maintained solutions within data canter settings.

# Practical Implementation e

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## Environment Setup

The practical segment was carried out using an Ubuntu 24.04 virtual machine. During the initial tryouts with Zabbix, some configuration problems arose which prompted a move to Prometheus and Grafana as shown in Fig. 1. The installation commands were as follows:

sudo apt update

sudo apt install grafana -y

sudo pip install prometheus\_client

The continuous operation of Prometheus was achieved through system service configuration.

## Custom Sensor Simulation

To simulate temperature and humidity data that updates every 5 seconds, a Python script was created (Fig. 2). This script exposes metrics via the URL http://localhost:8000/metrics utilizing the prometheus\_client library.

from prometheus\_client import start\_http\_server, Gauge

import random

import time

temperature\_gauge = Gauge('env\_temperature\_celsius', 'Simulated Room Temperature')

humidity\_gauge = Gauge('env\_humidity\_percent', 'Simulated Room Humidity')

def get\_fake\_sensor\_data():

temperature = round(random.uniform(18.0, 27.0), 2)

humidity = round(random.uniform(30.0, 60.0), 2)

return temperature, humidity

if \_\_name\_\_ == '\_\_main\_\_':

start\_http\_server(8000)

print("Serving fake sensor data on http://localhost:8000/metrics")

while True:

temp, hum = get\_fake\_sensor\_data()

temperature\_gauge.set(temp)

humidity\_gauge.set(hum)

time.sleep(5)

## Grafana Untegration

The setup allowed monitoring in real-time. Temperature and humidity trends were visualized with Grafana using Prometheus data, as shown in Fig 3. Panels were customized with color-coded thresholds (Fig. 4).

## Performance Monitoring

Resource usage estimation derived from system logs alongside Prometheus metrics indicate a consumption of approximately 160 MB of memory and less than 5% CPU during the testing period of 48 hours. Such a low resource footprint is advantageous for deploying on virtualized systems.

# Results and Comparative Analysis

As shown in Table I, Prometheus and Grafana performed well in producing dashboards—with a resource usage of 160 MB—though alerting features still required manual setup. The Python exporter recorded an average temperature of 22.5°C and humidity of 45% over the course of 48 hours, achieving 100% data uptime during that period (Fig. 6). As no other tools were explored, this further justifies the need to focus on improving this configuration for data center applications.

1. Tool comparison

|  |  |
| --- | --- |
| Metric | Value |
| Memory Usage | 160 MB |
| CPU Usage | <5% |
| Data Uptime | 100% (48 hours) |
| Average Temperature | 22.5°C |
| Average Humidity | 45% |

# Discussion

The frameworks Prometheus and Grafana stood out for their modularity as well as real-time visualizations, while the Python exporter guaranteed automatic data gathering. Data center needs were satisfied by the 5-second update interval [9], but alerting configuration presented some difficulties, indicating that default setups were necessary. The 160 MB resource consumption figure is far more attractive than industry standards of 300–500 MB [10], which makes it suitable for virtualized environments. Further research is required to test scalability limitations on multiple nodes.

# Future Work

Potential improvements could cover the following areas:

* Integration of Physical Sensors: Incorporating real sensors such as DHT22 for data collection and evaluating system performance in real-world settings.
* Automation of Alerts: Creating an automated plugin or script which sets alert parameters based on ASHRAE standards.
* Monitoring Over Multiple Nodes: Expanding the system to monitor several virtual machines or physical servers, thereby increasing its scalability.
* Tracking Energy Use: Including measurement parameters for energy consumption to assess the efficiency of HVAC systems from a holistic perspective.

These refinements would enhance the viability of using the system in actual data canter operations.

# Conclusion

This research confirms the practicality of using Prometheus and Grafana as a lightweight, open-source solution for HVAC data canter monitoring. Their implementation on an Ubuntu 24.04 VM alongside ASHRAE standard concepts demonstrates optimal uptime. These tools provide alerting functionality that need improvements; nevertheless, their modular structure and low resource consumption make them useful in scalable deployments. Further work will focus on automation of alerts and integration of physical sensors aimed at system improvements.

##### Acknowledgment *(Heading 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

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