VCC Assignment_3 Report

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1. Introduction

In this assignment, I developed a complete solution that integrates a local Linux VM running resource monitoring tools (Prometheus, Node Exporter, and Grafana) with Google Cloud Platform (GCP) auto-scaling capabilities. The goal was to monitor the resource usage on the local VM and trigger an autoscaling event on GCP when CPU usage exceeds 75%. This report documents every step of the process—from the setup of the VM to the final integration and testing of the autoscaling mechanism.

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2. Environment Setup and Prerequisites

Prerequisites:

- **Local Environment:**
  - A Windows machine with gcloud CLI installed.
  - A Linux VM (using VirtualBox) running on a host machine.
- **Software and Tools:**
  - **Oracle VirtualBox** for virtualization.
  - **Prometheus** for monitoring metrics.
  - **Node Exporter** for exposing system metrics.
  - **Grafana** for visualizing the metrics.
  - **Stress tool** to simulate high CPU usage.
  - **Google Cloud SDK (gcloud CLI)** for GCP configuration and autoscaling management.
  - **Python 3** with `psutil` installed for custom autoscaling script.

Installation Summary:

- **gcloud CLI** was installed on both Windows (for initial setup) and on the Linux VM (to execute autoscaling commands).
- **Prometheus**, **Node Exporter**, and **Grafana** were installed on the Linux VM.
- A separate GCP project was created for managing the instance groups and autoscaling.

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3. Local Virtual Machine (VM) Setup

Steps:

1. **Installing VirtualBox on Linux Host:**
   - Downloaded VirtualBox from the official website.
   - Installed VirtualBox using:
     ```
     sudo apt update
     sudo apt install virtualbox
     ```
2. **Creating the Virtual Machine:**
   - Opened VirtualBox and clicked "New."
   - Named the VM `LocalMonitoringVM` and selected the Linux OS type (Ubuntu 64-bit).
   - Allocated 2 CPUs and 4GB of RAM.
   - Created a new virtual hard disk (dynamic allocation, 20GB recommended).
3. **Installing Ubuntu Server on the VM:**
   - Downloaded the latest Ubuntu Server ISO from Ubuntu's official website.
   - Attached the ISO to the VM's optical drive.
   - Booted the VM and followed the installation wizard.
   - Performed system update:
     ```
     sudo apt update && sudo apt upgrade -y
     ```

Difficulties Encountered:

- **Network Configuration:**
  Initially faced issues with the VM's network settings (NAT vs. Bridged). Switching to Bridged Adapter resolved connectivity problems when accessing the VM from the host.

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4. Prometheus Setup and Configuration

Steps:

1. **Download Prometheus:**
   - Downloaded the Prometheus tar.gz file from Prometheus Downloads.
   - Command used:
     ```
     wget https://github.com/prometheus/prometheus/releases/download/v2.x.x/prometheus-2.x.x.linux-amd6
     ```
   - Extracted the tarball:
     ```
     tar xvfz prometheus-2.x.x.linux-amd64.tar.gz
     ```
2. **Navigating to Prometheus Directory and Running Prometheus:**
   - Changed directory:
     ```
     cd prometheus-2.x.x.linux-amd64
     ```
   - Started Prometheus with the default configuration:
     ```
     ./prometheus --config.file=prometheus.yml
     ```
3. **Verification:**
   - Accessed the Prometheus web interface via http://localhost:9090.

Configuration Changes:

- The default `prometheus.yml` file was used initially. Later, it was updated to include Node Exporter targets and alerting rules (see Section 5).

Difficulties Encountered:

- **Port Conflicts:**
  Initially, a port conflict occurred with another service running on port 9090. This was resolved by stopping the conflicting service.

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5. Node Exporter Setup

Steps:

1. **Download and Extract Node Exporter:**
   - Downloaded Node Exporter from its GitHub releases page.
   - Command:
     ```
     wget https://github.com/prometheus/node_exporter/releases/download/v1.x.x/node_exporter-1.x.x.linu
     tar xvfz node_exporter-1.x.x.linux-amd64.tar.gz
     cd node_exporter-1.x.x.linux-amd64
     ```
2. **Start Node Exporter:**
   - Ran the following command:
     ```
     ./node_exporter &
     ```
   - Verified by visiting http://localhost:9100/metrics.

Update Prometheus Configuration:

- Modified `prometheus.yml` to add Node Exporter as a target:

  ```
  scrape_configs:
    - job_name: 'prometheus'
      static_configs:
        - targets: ['localhost:9090']

    - job_name: 'node'
      static_configs:
        - targets: ['localhost:9100']
  ```

- Reloaded Prometheus configuration:

  ```
  curl -X POST http://localhost:9090/-/reload
  ```

Difficulties Encountered:

- **Path Issues:**
  Initially, the Node Exporter binary did not have execution permissions. This was resolved with:

  ```
  chmod +x node_exporter
  ```

---

6. Grafana Setup and Dashboard Configuration

Steps:

1. **Install Grafana:**
   - For Ubuntu, added the Grafana APT repository and installed:
     ```
     sudo apt-get install -y software-properties-common
     wget -q -O - https://packages.grafana.com/gpg.key | sudo apt-key add -
     echo "deb https://packages.grafana.com/oss/deb stable main" | sudo tee -a /etc/apt/sources.list.d/
     sudo apt-get update
     sudo apt-get install grafana
     ```
   - Started Grafana:
     ```
     sudo systemctl start grafana-server
     sudo systemctl enable grafana-server
     ```
2. **Configure Grafana:**
   - Accessed Grafana at http://localhost:3000.
   - Default credentials (admin/admin) were used for the initial login.
   - Added Prometheus as a data source:
     - URL: `http://localhost:9090`
     - Tested and saved the data source.
3. **Creating a Dashboard:**

- Created a new dashboard and added panels.
- Example query: `node_cpu_seconds_total` to display CPU metrics.

Difficulties Encountered:

- **Data Source Connection:**
  Initial connection issues with Prometheus as a data source were resolved by ensuring proper network accessibility between Grafana and Prometheus.

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7. GCP Project and gcloud CLI Configuration

Steps:

1. **GCP Project Setup:**
   - Created a new project in the GCP Console.
   - Enabled billing and necessary APIs (Compute Engine API).
2. **gcloud CLI Setup on Windows and Linux VM:**
   - Installed gcloud CLI following Google's installation guide.
   - Ran:
     `gcloud init`
   - Selected the created project and configured default settings.

Difficulties Encountered:

- **Authentication Issues:**
  On the Linux VM, initial gcloud authentication required opening a URL in a browser. This was handled by using a device code flow provided by gcloud.

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8. GCP Instance Template and Managed Instance Group (MIG)

Instance Template Creation:

- Ran the following command on the Linux VM (with gcloud configured):

```
gcloud compute instance-templates create my-instance-template \
    --machine-type=n1-standard-1 \
    --image-family=debian-10 \
    --image-project=debian-cloud \
    --boot-disk-size=10GB
```

- This template defined the VM characteristics (machine type, OS, disk size).

Managed Instance Group (MIG) Creation:

- Created the MIG with:

```
gcloud compute instance-groups managed create my-instance-group \
    --base-instance-name=my-instance \
    --size=1 \
    --template=my-instance-template \
    --zone=us-central1-a
```

- Verified the MIG in the GCP Console under **Compute Engine > Instance groups**.

Autoscaling Configuration:

- Configured autoscaling on the MIG:

```
gcloud compute instance-groups managed set-autoscaling my-instance-group \
    --max-num-replicas=5 \
    --target-cpu-utilization=0.75 \
    --cool-down-period=60 \
    --zone=us-central1-a
```

- This command instructs GCP to scale up to 5 instances when CPU utilization exceeds 75%.

Difficulties Encountered:

- **Zone Mismatch:**
  Initially, instances were being created in an incorrect zone due to misconfigured parameters. Ensured consistency by setting the zone explicitly in each command.

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9. Autoscaling Script Development

Direct Script Approach:

I chose to implement a Python script running on the Linux VM (with gcloud CLI installed) that monitors CPU usage via the `psutil` module and calls the GCP autoscaling command.

Script Details:

- **Script Name:** `autoscale_monitor.py`
- **Dependencies:** Python 3, psutil (`pip install psutil`)
- **Logic:**
  - Monitor CPU usage at 10-second intervals.
  - If usage > 75%, query the current size of the MIG.
  - If the size is below the maximum (5), increment the group size by 1.
  - Include a cooldown period (60 seconds) after each scaling event.

Script Code:

```python
import psutil
import subprocess
import time

# Configuration variables
THRESHOLD = 75.0          # CPU usage percentage to trigger scaling
MAX_SIZE = 5              # Maximum number of instances in the MIG
ZONE = "us-central1-a"    # Change as needed for your MIG
MIG_NAME = "my-instance-group"
COOLDOWN = 60             # Cooldown period in seconds after a scaling event

def get_current_mig_size():
    """Retrieve the current target size of the Managed Instance Group."""
    try:
        result = subprocess.check_output([
            "gcloud", "compute", "instance-groups", "managed", "describe", MIG_NAME,
            "--zone", ZONE,
            "--format=value(targetSize)"
        ])
        return int(result.decode("utf-8").strip())
    except subprocess.CalledProcessError as e:
        print("Error retrieving MIG size:", e)
        return None
```

```python
def resize_mig(new_size):
    """Resize the Managed Instance Group to the new size using gcloud CLI."""
    try:
        print(f"Resizing MIG {MIG_NAME} to {new_size} instances...")
        subprocess.check_call([
            "gcloud", "compute", "instance-groups", "managed", "resize", MIG_NAME,
            "--size", str(new_size),
            "--zone", ZONE
        ])
        print("Resize command executed successfully.")
    except subprocess.CalledProcessError as e:
        print("Error executing resize command:", e)

def monitor_and_scale():
    while True:
        # Measure CPU usage over an interval of 10 seconds
        cpu_usage = psutil.cpu_percent(interval=10)
        print(f"Current CPU Usage: {cpu_usage}%")

        if cpu_usage > THRESHOLD:
            print("Threshold exceeded! Checking current MIG size...")
            current_size = get_current_mig_size()
            if current_size is None:
                print("Skipping scaling due to error retrieving MIG size.")
            elif current_size >= MAX_SIZE:
                print(f"MIG is already at maximum size ({MAX_SIZE}). No scaling performed.")
            else:
                new_size = current_size + 1
                print(f"Scaling from {current_size} to {new_size} instances.")
                resize_mig(new_size)
                print(f"Cooling down for {COOLDOWN} seconds to allow scaling to take effect.")
                time.sleep(COOLDOWN)
        else:
            print("CPU usage is within limits. No scaling needed.")

        # Sleep before the next check (adjust as needed)
        time.sleep(10)

if __name__ == "__main__":
    monitor_and_scale()
```

Execution:

- Run the script on the Linux VM:

  `python3 autoscale_monitor.py`

- Verified that when running `stress --cpu 4 --timeout 120`, the script successfully triggered scaling commands on GCP.

Difficulties Encountered:

- **Script Permissions and Environment:**
  Ensured that the script had the correct permissions and that the gcloud CLI was available in the environment's PATH.
- **Gcloud CLI Command Output Parsing:**
  Occasionally, errors in parsing the MIG size were encountered; these were resolved by validating the output format.

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10. Testing and Demonstration

Steps for Testing:

1. **Baseline Monitoring:**
   - Verified Prometheus and Grafana were correctly displaying metrics from Node Exporter.
   - Confirmed local endpoints:
     - Prometheus: http://localhost:9090
     - Node Exporter: http://localhost:9100/metrics
     - Grafana: http://localhost:3000
2. **Stress Test:**
   - Ran:
     ```
     sudo apt-get install stress
     stress --cpu 4 --timeout 120
     ```
   - Monitored CPU usage via Prometheus and Grafana.
   - Observed the autoscaling script detecting high CPU usage and issuing a gcloud CLI command to increase the MIG size.
3. **GCP Verification:**
   - Logged into the GCP Console and verified that the Managed Instance Group size increased accordingly.
   - Reviewed logs from the autoscaling script to ensure commands were executed successfully.

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11. Challenges and Difficulties Encountered

VM Setup:

- **Networking Issues:**
  Initially encountered connectivity problems due to incorrect network adapter settings. Resolved by switching from NAT to Bridged Adapter.

Prometheus and Node Exporter:

- **Permission Issues:**
  Node Exporter required correct execution permissions.
- **Port Conflicts:**
  Resolved conflicts when another service was using Prometheus default port.

Grafana:

- **Data Source Configuration:**
  Faced temporary connectivity issues with Prometheus that were resolved by checking firewall and network settings.

GCP and gcloud CLI:

- **Authentication Flow:**
  The gcloud CLI required a device code flow on the Linux VM; this was an extra step that required browser authentication.
- **Zone Consistency:**
  Initially, autoscaling commands were misdirected due to zone mismatches.

Autoscaling Script:

- **Parsing CLI Output:**
  Ensured correct parsing of the gcloud CLI output for the MIG size.
- **Cooldown Logic:**
  Implemented a cooldown period to prevent rapid, repeated scaling events.

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12. Conclusion and Future Improvements

This project successfully integrates a local monitoring stack (Prometheus, Node Exporter, and Grafana) with GCP autoscaling, triggered via a custom Python script. The assignment demonstrated: - Setting up a local VM and installing necessary monitoring tools. - Configuring Prometheus and Grafana to monitor system metrics. - Setting up a GCP project, instance template, and Managed Instance Group. - Developing a Python script to trigger autoscaling based on CPU usage. - Testing the end-to-end flow using the stress tool to simulate high load.

Future Improvements:

- **Enhanced Logic:**
  Implement dynamic scaling (both up and down) based on additional metrics.
- **Alerting Integration:**
  Consider using Prometheus Alertmanager and webhooks for a more event-driven approach.
- **Logging and Monitoring:**
  Enhance logging within the autoscaling script for better diagnostics.
- **Security Hardening:**
  Secure the gcloud CLI environment and API keys.

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13. Appendix: Commands and Configuration Files

Prometheus Configuration (`prometheus.yml`):

```yaml
global:
  scrape_interval: 15s

scrape_configs:
  - job_name: 'prometheus'
    static_configs:
      - targets: ['localhost:9090']

  - job_name: 'node'
    static_configs:
      - targets: ['localhost:9100']
```

- Output

Node Exporter Setup:

```bash
wget https://github.com/prometheus/node_exporter/releases/download/v1.x.x/node_exporter-1.x.x.linux-amd64.t
tar xvfz node_exporter-1.x.x.linux-amd64.tar.gz
cd node_exporter-1.x.x.linux-amd64
chmod +x node_exporter
./node_exporter &
```

Grafana Installation Commands:

```bash
sudo apt-get install -y software-properties-common
wget -q -O - https://packages.grafana.com/gpg.key | sudo apt-key add -
echo "deb https://packages.grafana.com/oss/deb stable main" | sudo tee -a /etc/apt/sources.list.d/grafana.l
sudo apt-get update
sudo apt-get install grafana
sudo systemctl start grafana-server
sudo systemctl enable grafana-server
```

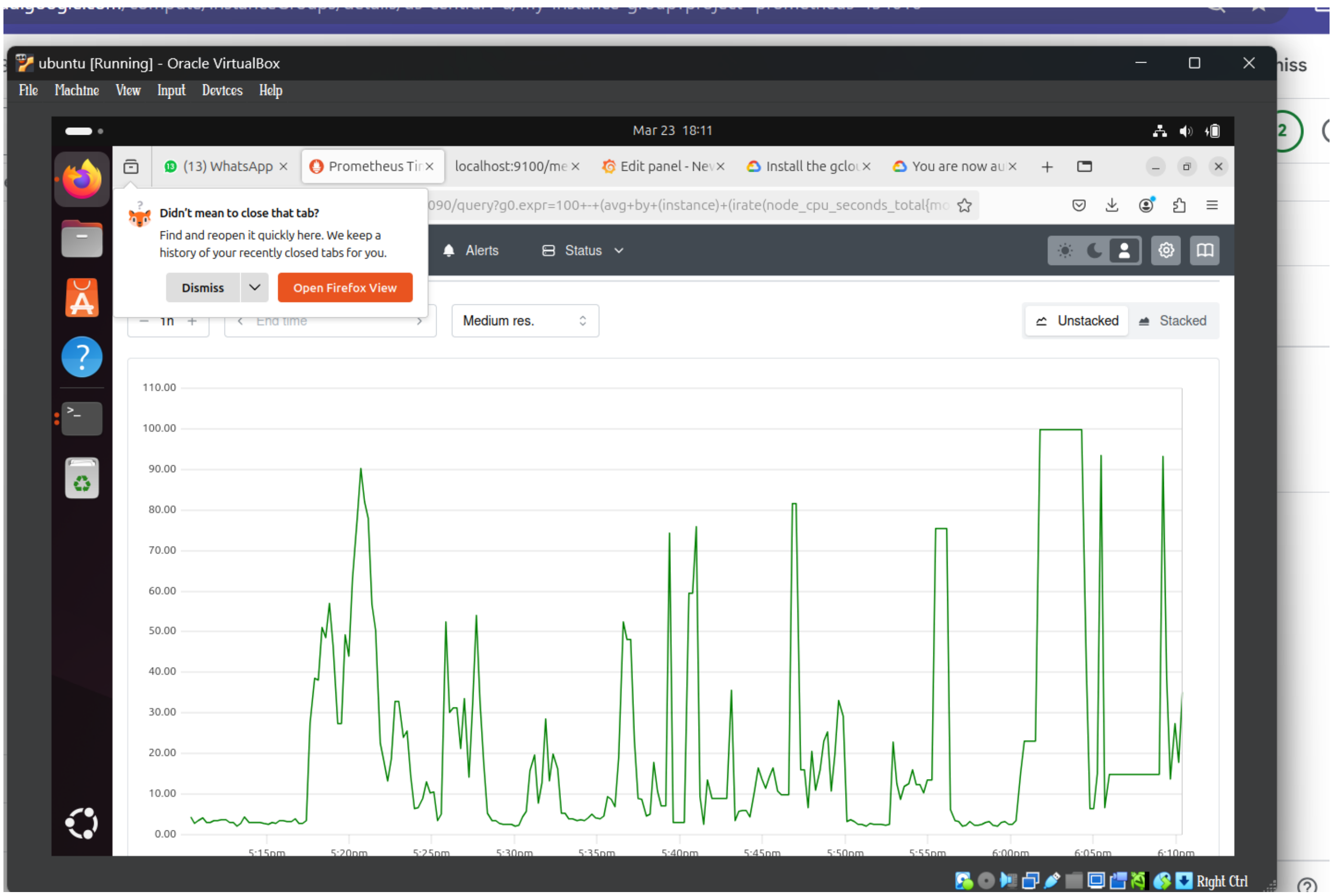


Figure 1: Prometheas

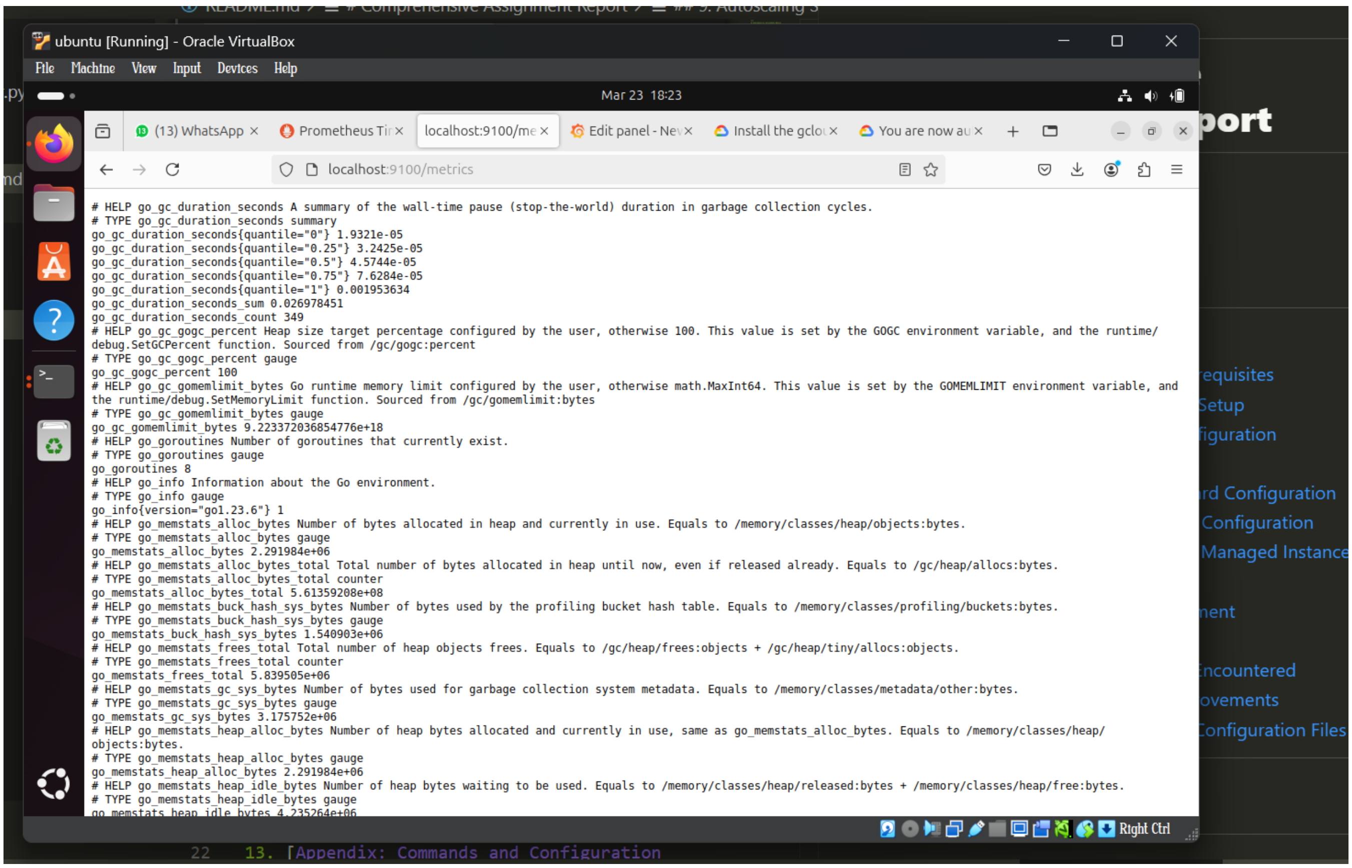
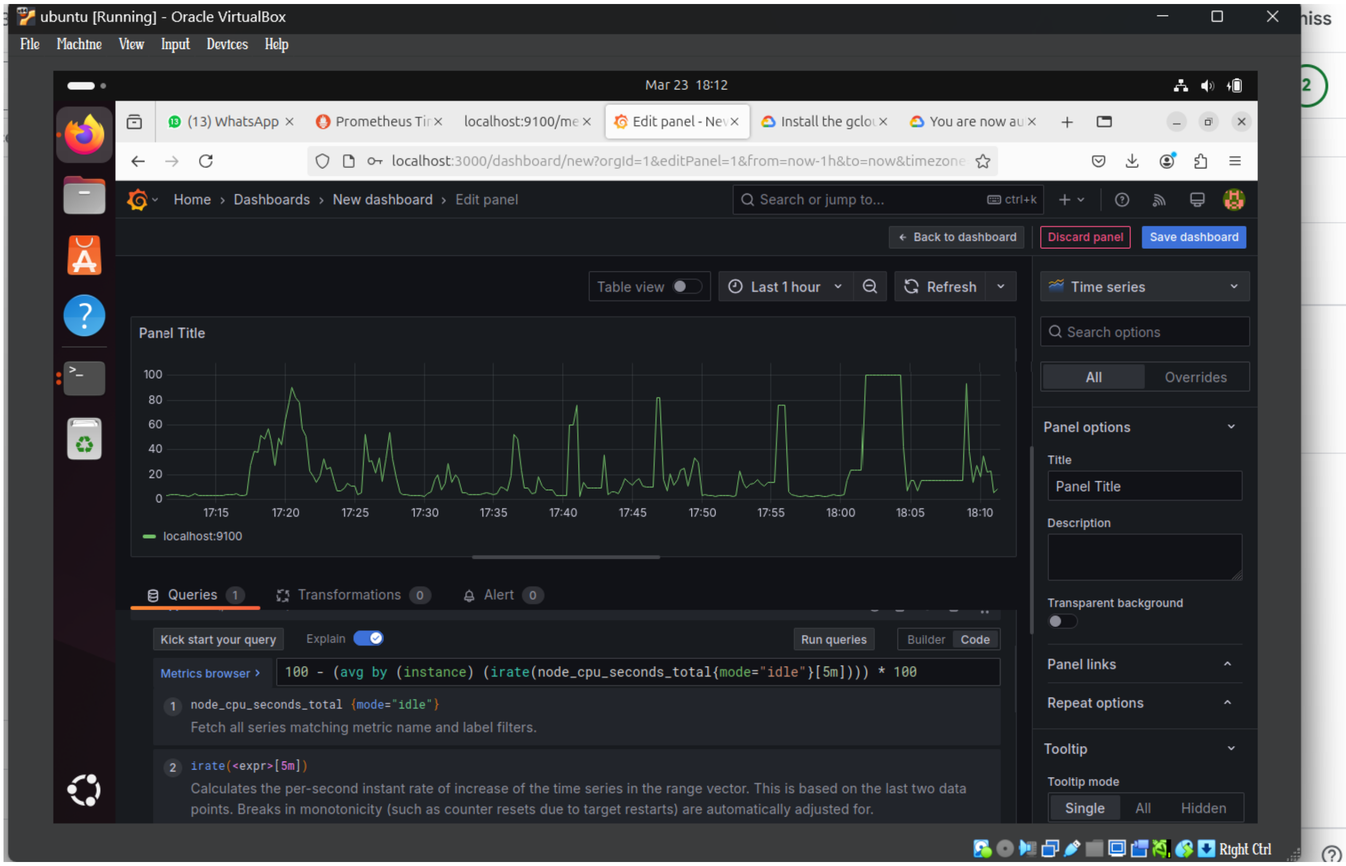


Figure 2: Node Explorer



GCP CLI and MIG Commands:

```
gcloud init
gcloud config set project YOUR_PROJECT_ID

gcloud compute instance-templates create my-instance-template \
    --machine-type=n1-standard-1\
    --image-family=debian-10 \
    --image-project=debian-cloud \
    --boot-disk-size=10GB \
    --metadata=startup-script="#!/bin/bash; apt-get update; apt-get install -y stress; stress --cpu 4 --tim

gcloud compute instance-groups managed create my-instance-group \
    --base-instance-name=my-instance \
    --size=2 \
    --template=my-instance-template \
    --zone=us-central1-a

gcloud compute instance-groups managed set-autoscaling my-instance-group \
    --max-num-replicas=5 \
    --target-cpu-utilization=0.75 \
    --cool-down-period=60 \
    --zone=us-central1-a
```

Autoscaling Script (`autoscale_monitor.py`):

(Refer to Section 9 for full code.)

Video Demo link

Link

14. Architecture Diagram and Flow

The following diagram represents the overall architecture and data flow for the project. It illustrates how the local VM and its monitoring stack interact with the GCP environment, triggering autoscaling and stress commands on new instances.

```
                                 +---------------------------------+
                                 |         GCP Project             |
                                 |                                 |
                                 |  Managed Instance Group (MIG)     |
                                 |  (Minimum: 2, Maximum: 5)         |
                                 |                                 |
                                 |  +---------------------------+  | <-- New instances created
                                 |  | Instance Template         |  |     with startup script that:
                                 |  | - Debian 11               |  |     - Installs stress tool
                                 |  | - Startup script:         |  |     - Executes stress command
                                 |  |   apt-get update;         |  |
                                 |  |   apt-get install -y stress|  |
                                 |  |   stress --cpu 4 --timeout 120 &  |
                                 |  +---------------------------+  |
                                 +---------------^-----------------+
                                                 |
                                                 |  Autoscaling Trigger
                                                 |  via gcloud CLI (from local script)
                                                 |
+-------------------------------------------------+
|                Local Linux VM                   |
|                                                 |
|  +----------------+     +---------------------+ |
|  | Prometheus     |<--->| Node Exporter       | |
|  | (Metrics: CPU  |     | (System metrics)    | |
|  | usage, etc.)   |     +---------------------+ |
|  +----------------+              |                |
|         |                (Scrapes metrics)   |
|         v                    |                |
|  +----------------+           |                |
|  | Grafana        |<----------+                |
|  | (Dashboard)    |                           |
|  +----------------+                           |
|         |                                   Autoscaling Script
|         v                                   (Python script monitors CPU usage)
|  +----------------------------+                (Triggers scaling and stress commands)
|  | Autoscaling Python Script  |-------------------------->
|  | (psutil & gcloud CLI)      |  <--- Runs stress on all instances
|  +----------------------------+
|                                                 |
+-------------------------------------------------+
```

Diagram Explanation:

- **Local Linux VM:**
  Hosts the monitoring stack (Prometheus and Node Exporter) and Grafana for visualization. It also runs the Python autoscaling script that monitors CPU usage using the `psutil` library.
- **Autoscaling Script:**
  When CPU usage exceeds 75%, the script uses the gcloud CLI to resize the Managed Instance Group (MIG) on GCP. It then remotely triggers the stress command on every instance (existing and new) using SSH.
- **GCP Managed Instance Group (MIG):**

Consists of instances created based on an instance template that has a startup script. The startup script installs and executes the stress command upon instance initialization.

- **Instance Template:**
  Defines the configuration for new instances (e.g., OS, machine type, disk size) and includes a startup script that automatically runs the stress command.

This comprehensive flow ensures that: 1. **Local Monitoring:**
The local VM monitors system performance using Prometheus and Grafana. 2. **Autoscaling:**
The autoscaling script triggers GCP autoscaling based on resource thresholds. 3. **New Instance Setup:**
Each new instance automatically runs the stress command as part of its startup process. 4. **Unified Workload Simulation:**
The stress command is executed both on the local VM (as part of the demonstration) and on every instance in the MIG, ensuring consistent workload simulation across the entire system.
