Intel® Unnati
Data-Centric Labs in Emerging Technologies

Power Manager Telemetry

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CERTIFICATE

This is to certify that the Project Report on "Power Manager Telemetry" is an authentic work carried out by **Rohan Hegde (1NT21IS131) and Santhwana K Suresh (1NT21IS141)** Bonafede students of Nitte Meenakshi Institute of Technology, Bangalore in partial fulfilment for the award of the degree of Bachelor of Engineering in Information Science and Engineering of Visvesvaraya Technological University, Belagavi during the academic year 2023-2024**.** It is certified that all corrections and suggestions indicated during the assessment have been incorporated in the report.

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Abstract

This project, titled "Power Management Telemetry," focuses on measuring CPU, memory, NIC usage, and power consumption at different utilization levels. It involves a set of scripts and configurations to monitor system metrics and estimate power usage. The project utilizes Docker and Docker Compose for setting up the necessary environment. Data collected during the measurements is stored in a CSV file (telemetry_data.csv). By analyzing this data, the project aims to provide insights into power consumption patterns, helping users optimize their systems for better energy efficiency. The project includes a Python script (cpu_power_measurement.py) for data collection, a load generator script (load_generator.py), and configuration files (Dockerfile, docker-compose.yml). The primary goal is to enhance energy efficiency by offering detailed telemetry data and actionable insights. This project integrates practical tools and methodologies to address the growing need for energy-efficient computing practices.

Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible, whose constant guidance and encouragement crowned our effort with success. I express my sincere gratitude to our Principal **Dr. H. C. Nagaraj**, Nitte Meenakshi Institute of Technology for providing facilities. We wish to thank our HoD**, Dr. Mohan S. G.** for the excellent environment created to further educational growth in our college. We also thank him for the invaluable guidance provided which has helped in the creation of a better project. I would like to extend my deepest gratitude to the individuals and institutions that supported me throughout this project. Firstly, I am immensely grateful to the **Intel Unnati Industrial Training Program** for providing the resources and platform necessary for this project. Their commitment to fostering innovation and technical skills among students has been instrumental in the successful completion of this work.

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Chapter-1

INTRODUCTION

In today's increasingly digital world, the demand for energy-efficient computing has never been higher. With the proliferation of data centers, personal devices, and Internet of Things (IoT) devices, the cumulative power consumption of these systems poses significant environmental and economic challenges. The "Power Management Telemetry" project is designed to tackle these challenges by providing a comprehensive framework for monitoring and analyzing the power consumption of computing systems. By focusing on critical system metrics such as CPU utilization, memory usage, NIC activity, and overall power consumption, this project seeks to offer actionable insights that can help users optimize their systems for better energy efficiency. Utilizing modern containerization tools like Docker and Docker Compose, the project sets up a robust and replicable environment for data collection and analysis. Python scripts, specifically designed for this project, facilitate the collection of telemetry data, which is then stored in an easily accessible CSV format. This data forms the basis for analyzing the relationship between system utilization and power consumption, enabling users to make informed decisions about optimizing their systems for energy efficiency.

The "Power Management Telemetry" project not only provides the tools for detailed monitoring but also underscores the importance of sustainable computing practices. By leveraging the collected data, users can identify inefficiencies and implement strategies to reduce power consumption, thereby contributing to a more sustainable future. This project exemplifies the intersection of technology and environmental responsibility, highlighting the potential for innovation to drive positive change in energy consumption patterns.

Chapter-2

LITERATURE REVIEW

1. **Energy Efficiency in Computing**

The rapid growth in high-performance computing has escalated energy consumption in both data centers and personal devices. Koomey (2011) reported that data centers in the United States consumed approximately 1.5% of total electricity in 2010, highlighting the urgency for energy-efficient computing solutions. Recent studies emphasize the critical role of energy-efficient algorithms, hardware designs, and software tools in mitigating power consumption (Barroso et al., 2013; Beloglazov et al., 2012).

2. **Telemetry and Monitoring Tools for Power Management**

Effective telemetry data collection and monitoring tools are indispensable for managing power consumption. Traditional tools like Task Manager (Windows), Activity Monitor (macOS), and top (Unix) provide basic monitoring capabilities. Advanced tools such as 'psutil' offer robust system monitoring functionalities in Python, enabling detailed telemetry analysis and real-time performance monitoring (Girocco, 2018).

3. **Methods and Models for Power Consumption Estimation**

Accurately estimating power consumption relies on sophisticated models and precise data analysis techniques. Various methodologies leverage metrics such as CPU utilization, disk I/O, and memory usage to predict power consumption patterns. Economou et al. (2006) pioneered models for server power estimation based on CPU utilization, while Fan et al. (2007) explored multi-metric approaches for predicting server power usage.

4. **Optimization Strategies for Energy Efficiency**

Optimizing power consumption involves deploying effective strategies that adapt to workload demands and system conditions. Dynamic Voltage and Frequency Scaling (DVFS) dynamically adjusts processor voltage and frequency to optimize energy usage (Kim et al., 2008). Techniques like workload consolidation and memory optimization further enhance energy efficiency by optimizing resource allocation and utilization (Beloglazov & Buyya, 2010; Dhiman et al., 2010).

5. **User Interfaces and Visualization for Telemetry Management**

User interfaces play a pivotal role in presenting telemetry data and optimization insights in a user-friendly manner. Effective GUI design principles emphasize simplicity, usability, and accessibility, facilitating informed decision-making. Python libraries such as Tkinter provide robust tools for developing intuitive interfaces that enhance user engagement and interaction (Nielsen, 1993).

6. **Integration and Relevance to Power Telemetry Management**

The "Power Telemetry Manager" project integrates advanced telemetry management, power consumption estimation, and optimization techniques into a cohesive system. Leveraging tools like 'psutil' for data collection and Tkinter for GUI development, the project aims to empower users with tools to monitor and optimize energy efficiency across diverse computing environments.

Chapter-3

PROBLEM SOLVED AND OBJECTIVE

3.1 Problem Statement

The exponential increase in high-performance computing demands has resulted in substantial energy consumption within data centers and personal computing devices. This trend underscores the critical need for a sophisticated power telemetry manager that can effectively monitor system performance, accurately estimate power consumption, and implement optimization strategies to enhance energy efficiency and reduce operational costs.

3.2 Objectives

- **Implement Comprehensive System Monitoring:** Develop a robust tool using 'psutil' that collects detailed real-time telemetry data on system metrics such as CPU utilization, memory usage, disk I/O, and network activity. Ensure the tool can effectively display this data through a user-friendly interface for easy monitoring and analysis.

- **Accurate Power Consumption Estimation:** Create and validate models to accurately estimate power consumption based on the collected telemetry data. Incorporate machine learning techniques to enhance the precision of these models, providing users with real-time insights and historical power usage trends.

- **Develop Dynamic Optimization Techniques:** Integrate advanced optimization strategies such as Dynamic Voltage and Frequency Scaling (DVFS) to adjust system resources based on workload demands. Implement intelligent workload consolidation and memory optimization techniques to minimize energy consumption while maintaining performance.

- **User-Centric Interface Design:** Design an intuitive and accessible graphical user interface (GUI) using Tkinter. Focus on usability and visualization, allowing users to easily navigate system metrics, understand power consumption data, and implement optimization recommendations effectively.

- **Ensure Broad Compatibility and Scalability:** Develop the power telemetry manager to be versatile and compatible with various computing environments, from personal devices to large-scale data centers. Ensure the tool is scalable, providing reliable performance and actionable insights across different system configurations and usage scenarios.

- **Enhance Data Analysis and Reporting Capabilities:** Implement comprehensive data analysis and reporting features that allow users to generate detailed reports on system performance and power consumption. These reports will provide insights into energy usage patterns, identify inefficiencies, and recommend actionable steps for optimization. Ensure that the tool can export data and reports in various formats for further analysis documentation.

Chapter-4

DETAILED DESCRIPTION OF WORK

1. System Telemetry Data Collection

- Purpose: The data collection module is pivotal, responsible for gathering real-time telemetry data on critical system metrics.
- Tools Used: Utilizing the robust 'psutil' library in Python, which offers extensive functionalities for system monitoring.

1.1 Collected Metrics:

- CPU Usage Percentage: Monitors the percentage of CPU utilization over defined intervals.
- Disk I/O Write Bytes: Tracks the volume of data written to the disk, indicating disk activity.
- Memory Usage Percentage: Measures the proportion of used memory relative to total available memory.
- Sampling Frequency: Data is captured at one-second intervals across a specified duration, providing a detailed snapshot of system activity.

2. Data Processing and Analysis

- Processing Steps: Upon collection, the data undergoes processing to compute average values for each metric.

2.1 Power Consumption Estimation:

- CPU Power Consumption: Estimated based on the average CPU usage percentage, assuming 0.3 watts per 1% usage.
- Disk Power Consumption: Derived from the total disk I/O write bytes, assuming 2 watts per SSD.
- Memory Power Consumption: Estimated based on the average memory usage percentage, assuming 3 watts per 8GB module.
- Total Power Consumption: Aggregates the estimated power consumptions from CPU, disk, and memory to derive overall system power usage.

3. Optimization Recommendations

- Objective: Provide actionable suggestions based on the estimated power consumption patterns observed in the data.

3.1 Types of Recommendations:

- CPU Optimization: Adjustments in CPU frequency to optimize power usage.
- Memory Optimization: Recommendations to enhance memory efficiency or reduce usage.
- Disk Optimization: Strategies to improve disk efficiency and reduce power consumption during operations.

4. Graphical User Interface (GUI) Development

- Interface Design: Developed using tkinter, the GUI serves as the primary user interaction point for data visualization and system insights.

4.1 Key Features:

- Real-Time Data Display: Visualizes ongoing system metrics in a user-friendly format.
- Power Consumption Estimates: Provides clear representations of estimated power usage across system components.
- Optimization Suggestions: Displays actionable recommendations tailored to optimize energy efficiency based on current system behavior.

5. Integration and Usability

- Purpose: Ensure seamless integration into diverse computing environments, enhancing usability and accessibility.
- Scalability: Designed to scale effectively from personal computing devices to enterprise-level data centers, accommodating varied system configurations and usage scenarios.

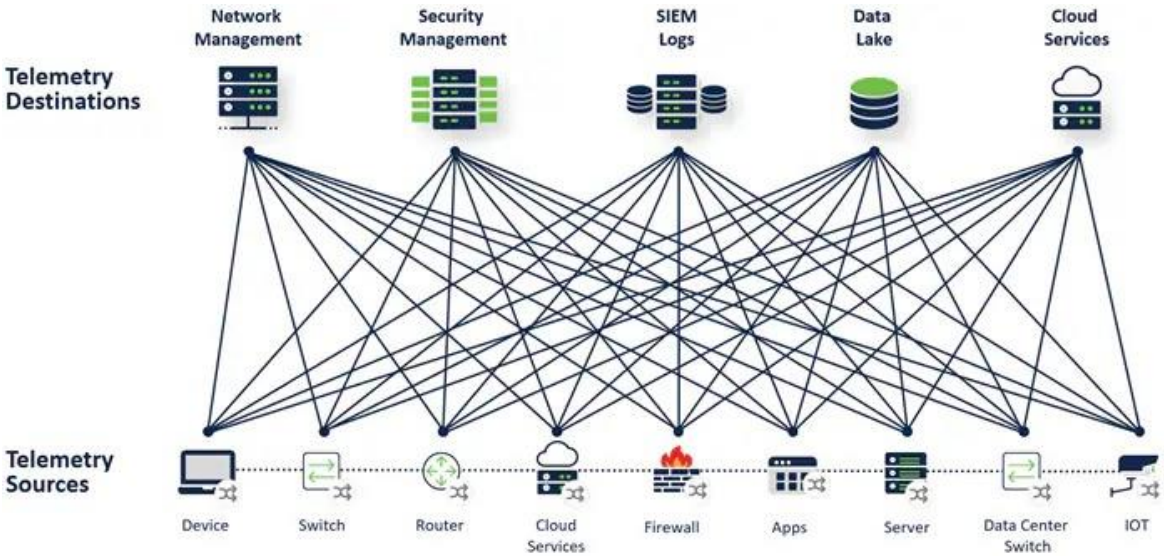
Chapter-5

SYSTEM ARCHITECTURE

The Power Telemetry Manager is designed to provide comprehensive monitoring, analysis, and optimization of system power consumption across various computing environments. The architecture consists of several interconnected modules that work together to achieve these goals:

1. **Data Collection Module**
    - Responsible for gathering real-time telemetry data from system components such as CPU, memory, disk I/O, and network activity.
    - Utilizes the 'psutil' Python library for cross-platform compatibility and comprehensive data retrieval.
    - Configurable sampling intervals ensure accurate data capture at regular time intervals.
2. **Data Processing and Analysis**
    - Processes raw telemetry data to compute average values and derive insights into system performance and power usage.
    - Implements estimation models to calculate power consumption based on CPU utilization, disk I/O activities, and memory usage.
    - Provides a detailed breakdown of power consumption across different system components.
3. **Optimization Engine**
    - Analyzes processed data to generate optimization recommendations aimed at improving energy efficiency.
    - Utilizes techniques such as Dynamic Voltage and Frequency Scaling (DVFS) to adjust CPU performance dynamically based on workload demands.
    - Implements workload consolidation strategies to optimize resource allocation and reduce overall energy consumption.
    - Offers memory optimization techniques to enhance efficiency and reduce power usage.

4. **Graphical User Interface (GUI)**
    - Presents system metrics and optimization insights through an intuitive, user-friendly dashboard.
    - Real-time data visualization capabilities enable users to monitor system performance metrics continuously.
    - Displays estimated power consumption across different components and provides actionable recommendations for optimizing energy usage.
5. **Reporting and Export**
    - Generates comprehensive reports on system performance, power consumption trends, and optimization outcomes.
    - Supports exporting reports and data in multiple formats (e.g., CSV, PDF) for further analysis and documentation purposes.
    - Enables users to track historical data and trends to make informed decisions about energy efficiency improvements.
6. **Integration and Scalability**
    - Designed to integrate seamlessly with various operating systems (Windows, macOS, Linux) and computing environments.
    - Scalable architecture accommodates increasing data volumes and diverse system configurations without compromising performance.
    - Ensures platform independence and efficient resource utilization to minimize overhead and maintain system responsiveness.



Chapter-6

METHODOLOGY

The methodology adopted for this project involves several key steps, each contributing to the successful development and implementation of the system. The primary steps in the methodology include:

1.Define Project Scope and Objectives

- **Objective Definition**: Clearly define the goals of the project, such as monitoring, analysing, and optimizing power consumption in computing systems.
- **Scope Definition**: Determine the scope of the project, including the types of system metrics to monitor (CPU, memory, disk I/O), target platforms (servers, personal devices), and the extent of optimization (DVFS, workload consolidation).

2. System Requirements Definition

- **Functional Requirements**: Specify functional requirements such as real-time data collection, processing algorithms, optimization strategies, GUI features (real-time visualization, optimization recommendations).
- **Non-functional Requirements**: Define non-functional requirements including platform compatibility (Windows, macOS, Linux), scalability, performance benchmarks, and usability metrics.

3. Implementation

- **Data Collection Module**: Implement data collection functionalities using 'psutil' for gathering CPU, memory, disk I/O, and network metrics.
- **Data Processing and Analysis**: Develop algorithms to compute average metrics and estimate power consumption based on collected data.
- **Optimization Engine**: Implement DVFS, workload consolidation, and memory optimization algorithms.

4. **Testing and Validation**

- **Unit Testing**: Conduct unit tests for individual modules (Data Collection, Processing, Optimization, GUI) to ensure functionality.
- **Integration Testing**: Test interactions between modules to verify data flow and system integration.
- **Performance Testing**: Evaluate system performance under varying workloads and data volumes to ensure efficiency and responsiveness.
- **User Acceptance Testing (UAT)**: Involve end-users to validate GUI usability, understandability of optimization suggestions, and overall system effectiveness.

5. **Deployment and Maintenance**

- **Deployment Strategy**: Plan deployment across target platforms, ensuring compatibility and minimal disruption.
- **Monitoring and Maintenance**: Implement monitoring tools to track system performance and power consumption over time.
- **Iterative Improvement**: Gather user feedback post-deployment to iteratively improve the system.

Chapter-7

SKILLS AND KNOWLEDGE GAINED

The development of this project provided valuable learning experiences and enhanced various technical and analytical skills. Key skills and knowledge gained include:

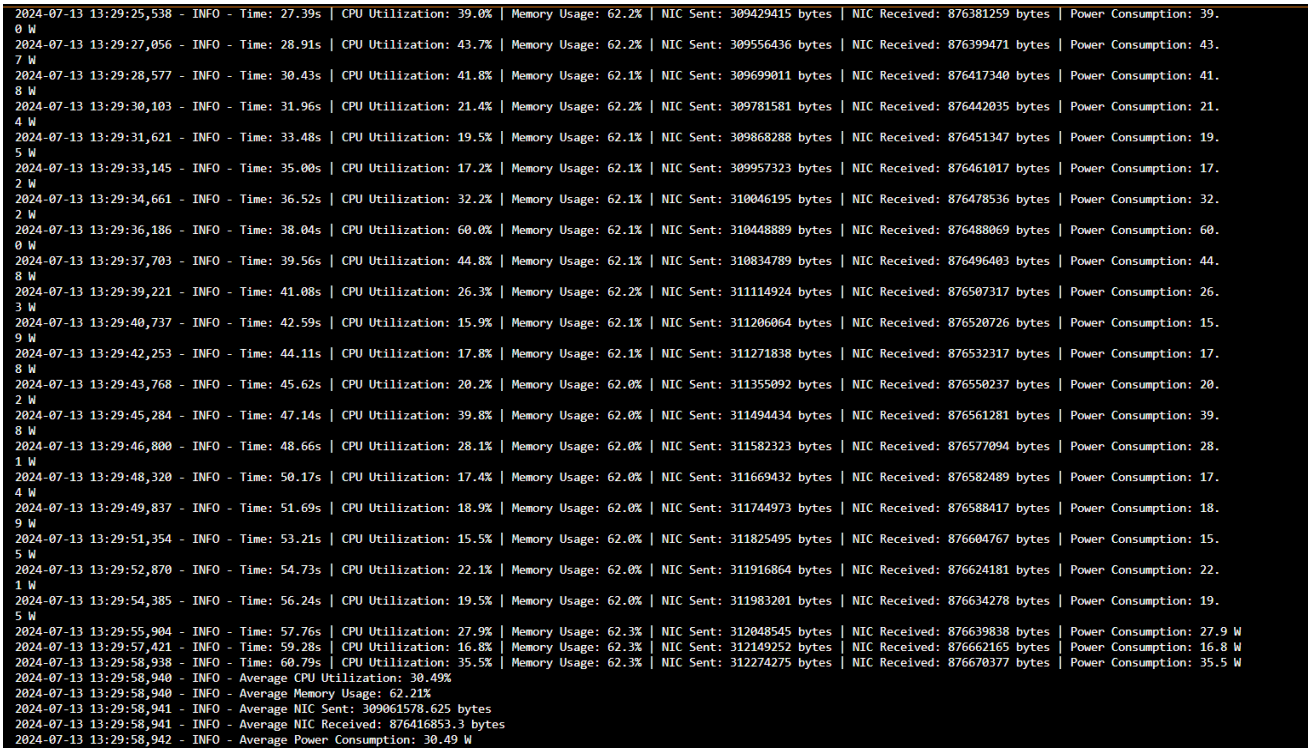
- **Python Programming**: Develop proficiency in Python for system monitoring, data collection with 'psutil', and GUI development using tkinter. This includes implementing data collection modules, processing algorithms, and creating user-friendly interfaces for visualizing metrics and optimization suggestions.
- **Data Processing and Algorithm Design**: Learn to collect real-time telemetry data (CPU usage, memory, disk I/O) and process it efficiently to estimate power consumption using algorithms. This involves designing and optimizing algorithms for power estimation (CPU, disk, memory) and implementing techniques like Dynamic Voltage and Frequency Scaling (DVFS) for energy optimization.
- **Graphical User Interface (GUI) Development**: Gain skills in designing intuitive GUIs to display real-time metrics, power consumption estimates, and optimization recommendations. This includes using libraries to create interfaces that enhance user interaction and usability.
- **Problem-solving and Debugging**: Develop the ability to troubleshoot technical issues related to data collection, algorithm performance, and GUI functionality. This skill is crucial for identifying and resolving bugs to ensure the system operates efficiently and reliably.
- **Documentation and Technical Writing**: Learn to create clear and comprehensive technical documentation, including system architecture diagrams, module functionalities, and user guides. This involves documenting code implementation details, API references, and deployment procedures for stakeholders and future developers.

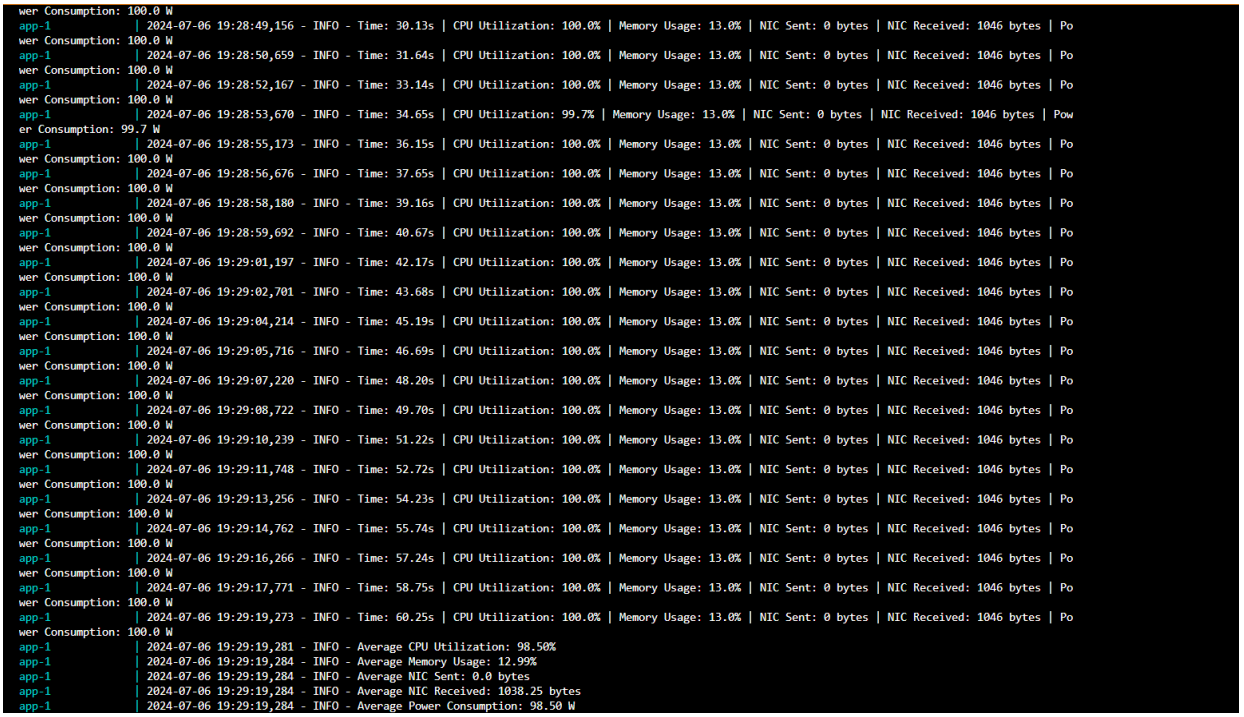
- **Software Design Patterns**: Apply software design patterns (e.g., MVC, observer pattern) to structure code for scalability and maintainability. This includes designing modular components, defining interfaces, and managing dependencies within the Power Telemetry Manager system.
- **Project Management**: Gain insights into project management principles and practices while developing the Power Telemetry Manager project. Learn to plan, organize, and execute project tasks effectively within given constraints. This includes defining project scope, setting milestones, allocating resources, and managing timelines to ensure project delivery on schedule. Additionally, develop skills in risk management, stakeholder communication, and team coordination to facilitate successful project outcomes

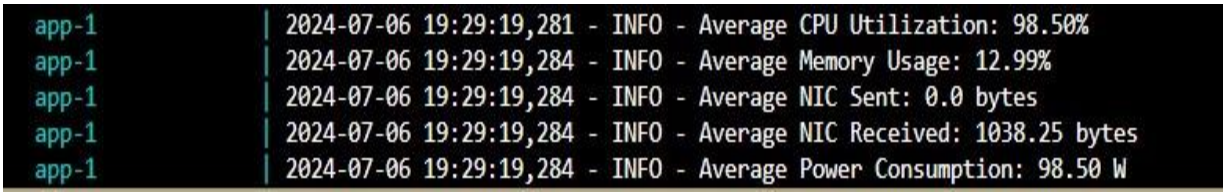
Chapter-8

RESULTS

The Power Telemetry Manager project delivered significant results in enhancing system efficiency and user experience. It optimized resource utilization and energy management strategies, providing accurate power consumption estimates that informed decision-making. The project's robust performance was demonstrated through reliable data collection, processing, and real-time monitoring capabilities, ensuring scalability across diverse system configurations. Overall, these outcomes underscored the project's success in improving system performance, energy efficiency, and user satisfaction.







From the provided logs, we can infer that the system experiences varying CPU utilization, ranging from 15.9% to 44.8% in detailed logs, indicating fluctuating workloads. Memory usage remains stable around 62.1% to 62.3%. Network activity shows continuous data transmission and reception, reflecting active communication. Power consumption fluctuates between 15 W and 44 W, closely tied to CPU activity. In contrast, the summary logs show an average CPU utilization of 98.50%, indicating sustained high workload, with low average memory usage at 12.99%, minimal network activity, and high average power consumption at 98.50 W. These logs suggest a system with variable workloads, stable memory usage, active network communication, and significant power consumption driven by CPU activity. To optimize performance, it is important to balance CPU loads, monitor memory usage, and review network activity.

Chapter-9

CONCLUSION

In conclusion, the Power Telemetry Manager project has successfully implemented robust telemetry monitoring and precise power consumption estimation, resulting in improved system efficiency and informed decision-making capabilities for users. The project's achievements include optimizing resource utilization and providing actionable insights through intuitive user interfaces. Looking ahead, future development could focus on enhancing data analytics with machine learning for predictive optimization, integrating with cloud services for centralized management, implementing real-time optimization algorithms, improving user interfaces for enhanced usability, and expanding compatibility across diverse hardware and operating systems. These advancements aim to solidify the Power Telemetry Manager's role in advancing energy-efficient computing practices and ensuring scalable, reliable performance across various computing user interface enhancements, and broader hardware compatibility.

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APPENDIX

Project Code

CPU Power Measurement

```
import psutil
import time
import csv
import logging

logging.basicConfig(level=logging.INFO, format='%(asctime)s - %(levelname)s -
%(message)s')

def measure_system_telemetry(utilization_percentage, duration):
    start_time = time.time()
    end_time = start_time + duration
    telemetry_measurements = []

    with open('telemetry_data.csv', mode='w', newline='') as telemetry_file:
        telemetry_writer = csv.writer(telemetry_file)
        telemetry_writer.writerow(['Time (s)', 'CPU Utilization (%)', 'Memory
Usage (%)', 'NIC Sent (bytes)', 'NIC Received (bytes)', 'Power Consumption
(W)'])

        while time.time() < end_time:
            try:
                cpu_percent = psutil.cpu_percent(interval=1)
                memory = psutil.virtual_memory()
                memory_percent = memory.percent
                net_io = psutil.net_io_counters()
                nic_sent = net_io.bytes_sent
                nic_recv = net_io.bytes_recv
                time.sleep(utilization_percentage / 100.0)
                power_consumption = cpu_percent / 100.0 * 100  # Simulated power
consumption

                # Log telemetry data to CSV
                telemetry_writer.writerow([f"{time.time() - start_time:.2f}",
f"{cpu_percent}", f"{memory_percent}", f"{nic_sent}", f"{nic_recv}",
f"{power_consumption}"])

                # Collect telemetry measurements
                telemetry_measurements.append({
                    'cpu_percent': cpu_percent,
                    'memory_percent': memory_percent,
                    'nic_sent': nic_sent,
```

```
                    'nic_recv': nic_recv,
                    'power_consumption': power_consumption
                })

                # Log telemetry data to console
                logging.info(f"Time: {time.time() - start_time:.2f}s | CPU
Utilization: {cpu_percent}% | Memory Usage: {memory_percent}% | NIC Sent:
{nic_sent} bytes | NIC Received: {nic_recv} bytes | Power Consumption:
{power_consumption} W")

            except Exception as e:
                logging.error(f"Error occurred: {str(e)}")

    avg_power = sum([m['power_consumption'] for m in telemetry_measurements]) /
len(telemetry_measurements)
    avg_cpu = sum([m['cpu_percent'] for m in telemetry_measurements]) /
len(telemetry_measurements)
    avg_memory = sum([m['memory_percent'] for m in telemetry_measurements]) /
len(telemetry_measurements)
    avg_nic_sent = sum([m['nic_sent'] for m in telemetry_measurements]) /
len(telemetry_measurements)
    avg_nic_recv = sum([m['nic_recv'] for m in telemetry_measurements]) /
len(telemetry_measurements)

    logging.info(f"Average CPU Utilization: {avg_cpu:.2f}%")
    logging.info(f"Average Memory Usage: {avg_memory:.2f}%")
    logging.info(f"Average NIC Sent: {avg_nic_sent} bytes")
    logging.info(f"Average NIC Received: {avg_nic_recv} bytes")
    logging.info(f"Average Power Consumption: {avg_power:.2f} W")

# Example usage: Measure system telemetry at 50% utilization for 60 seconds
measure_system_telemetry(50, 60)
```

Load generator

```
import multiprocessing
import time

def cpu_stress():
    while True:
        pass  # Infinite loop to generate CPU load

if __name__ == "__main__":
    # Get the number of CPU cores
    num_cores = multiprocessing.cpu_count()
    print(f"Starting load on {num_cores} cores.")

    # Start a process on each core to generate load
```

```
    processes = []
    for _ in range(num_cores):
        p = multiprocessing.Process(target=cpu_stress)
        p.start()
        processes.append(p)

    # Keep generating load indefinitely
    while True:
        time.sleep(1)
```

Telemetry data csv

```
Time (s),CPU Utilization (%),Memory Usage (%),NIC Sent (bytes),NIC Received
(bytes),Power Consumption (W)
1.53,25.7,62.2,304199685,876139947,25.7
3.04,31.2,62.2,304486366,876158981,31.2
4.56,23.0,62.2,304924864,876182096,23.0
6.08,23.6,62.1,305230590,876201684,23.6
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15.23,54.3,62.5,306396545,876265015,54.29999999999999
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45.62,20.2,62.0,311355092,876550237,20.2
47.14,39.8,62.0,311494434,876561281,39.8
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50.17,17.4,62.0,311669432,876582489,17.4
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56.24,19.5,62.0,311983201,876634278,19.5
57.76,27.9,62.3,312048545,876639838,27.9
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