# Chapter - 6
## Conclusion and Future Work

This chapter describes the research activity and its outcomes versus the predicted results as thought throughout the design phase. A complete analysis is being carried out to estimate future possibilities and enhancement to the system gained as a consequence of the suggested study. The study also discusses the important challenges/issues that could be investigated further to move it ahead.

## 6.1 Findings and Conclusions

By comparing the results of using the FCFS task scheduling algorithm in a Fog and cloud context, it appears that FCFS in the Fog environment better optimizes latency, total network utilization, and energy consumption. In contrast to cloud environments, latency, quality of service, and cost are all improved by using the fuzzy series parallel preprocessing resource scheduling algorithm in a Fog setting.

Latency and power consumption can be minimized by using the Shortest Job First Heuristic approach to schedule work. Much like the preemptive task priority network, the resource allocation technique greatly improves both QoS and efficiency.

Rule-based fuzzy network often known as fuzzy logic, is a resource scheduling technique that optimizes both latency and energy usage. In a similar vein, the QoS may be significantly optimized with the Fault, Configuration, Accounting, Performance, and Security methods.

## 6.2 Summarization of Hypotheses Testing Results

The comparison between fog-based and cloud-based systems based on execution time ($H_01$) demonstrates that using smart fog-based systems results in a significant decrease in execution time when compared to cloud-based systems. With values of 9872, 3008, 7866, 5417, 4533, 4024, and 8703, respectively, there is a significant reduction in execution time in the Fog systems 8:10, 9:9, 7:10, 6:10, 6:6, 4:10, and 2:6. It is therefore abundantly evident that the Fog layer is crucial to cutting down on execution time.

The comparison of Fog-based and Cloud-based systems based on latency ($H_02$) reveals that there is a significant reduction in latency with the usage of Smart Fog-based systems as opposed to Cloud-based systems. There is a significant reduction in latency value in the Fog system 10:5, 4:4, 2:5, 2:4, 2:3, 2:2, 1:5, 1:4, 1:3, 1:2, and 1:1,

such as 453.52, 198.92, 190.69, 198.13, 199.71, 201.36, 191.91, 197.73, 199.41, 201.16, and 194.08. As a result, the fog layer plays a crucial role in latency reduction.

The evaluation between Fog-based and Cloud-based systems based on energy consumption reveals a significant reduction in energy consumption when using Smart Fog-based systems against Cloud-based systems ($H_0 3$). There is a significant reduction in energy consumption in the fog systems 10:5, 5:5, 4:5, 4:4, 3:5, 2:5, 2:4, 2:3, 2:2, 1:5, 1:4,1:3, 1:2 and 1:1. Hence, based on the performance measure energy used, it is apparent that there is a considerable difference between the SMART FOG protocol-based system and the cloud-based system.

The analysis of Fog fog-based systems and Cloud cloud-based systems based on cost of execution reveals that there is a significant cost of execution decrease with the usage of Smart Fog-based systems as compared to Cloud-based systems ($H_0 4$). There is a significant cost reduction in the Fog system 10:5, 6:10, 5:5, 4:5, 4:4, 3:10, 3:5, 2:9, 2:8, 2:6, 2:5, 2:4, 2:3, 2:2, 1:5, 1:4, 1:3, 1:2, and 1:1. Hence, based on the performance measure cost of execution, it is evident that there is a considerable difference between the SMART FOG protocol-based system and the cloud-based system.

The comparison between Fog-based system and Cloud cloud-based system based on total network usage reveals that there is a significant decrease in total network usage when using a Smart Fog-based system against Cloud-based systems ($H_0 5$).In the fog system, there is a significant reduction in overall network utilization such as 813124, 100000, 100000, 889585, 100000, 717690, 600582.6, 100000, 560311.2, 200000, 100000, 376389.8, 300487.8, 226130, 151466.2, 187988.4, 150136.4, 112806.6, 75270.6, and 38142.7. Hence, based on the performance measure of total network use, it is apparent that there is a considerable difference between the SMART FOG protocol-based system and the cloud-based system.

The analysis of Fog-based and Cloud-based systems based on computational power consumed reveals a significant reduction in computational power consumed when using Smart Fog-based systems against Cloud-based systems ($H_0 6$). There is a significant reduction in computational power consumed by Fog systems in all cases when compared to cloud-based systems, implying that there is a significant difference between SMART FOG protocol-based systems and cloud-based systems based on the

performance measure computational power consumed by Fog devices in comparison to Cloud devices. For statistical validation of our findings, various null hypotheses were tested and the outcomes of these tests are as follows:

**Table 6.1: Chi-Square ($\chi^2$) Test for Awareness Level**

| Sr. No. | Hypothesis | Result @ 5 % Level |
|---|---|---|
| $H_0 1$ | There is no significant difference between SMART FOG protocol-based system and cloud-based system based on the performance measure execution time. | Rejected |
| $H_a 2$ | There is a significant difference between SMART FOG protocol-based System and cloud-based systems based on the performance measure latency. | Accepted |
| $H_0 3$ | There is no significant difference between SMART FOG protocol-based system and cloud-based system based on the performance measure energy consumed. | Rejected |
| $H_a 4$ | There is significant difference between SMART FOG protocol-based system and cloud-based system based on the performance measure cost of execution. | Accepted |
| $H_0 5$ | There is no significant difference between SMART FOG protocol-based system and cloud-based system based on the performance measure of total network usage. | Rejected |
| $H_a 6$ | There is a significant difference between SMART FOG protocol-based system and cloud-based system based on the performance measure computational power consumed. | Accepted |

Table 6.1, can be concluded that the hypothesis "SMART FOG protocol-based technique to create Fog Computing environment will share computational power to IoT devices with low computational power and other aspects" is being accepted which suggests that SMART FOG protocol-based technique reduces computational power consumption for the Fog devices and share computational power with IoT devices by lower the total consumption.

Finally, the hypothesis "$H_a 1$: SMART FOG protocol-based technique to create Fog Computing environment will share computational power to IoT devices with low computational power and other aspects" is accepted, implying that the SMART FOG protocol-based technique reduces computational power consumption for Fog devices and shares computational power with IoT devices by lowering total consumption.

## 6.3 Use of Machine Learning Techniques for Task Scheduling

It was discovered that when the K-Star classifier was employed for task scheduling, it properly identified around 91% of the cases, which was much higher than the other classification approaches tested, such as IBK, Logistic Regression, and AdaBoostM1. Similarly, the accuracy, recall, and F-measure values of 0.92, 0.91, and 0.90 were greater in comparison to IBK, Logistic Regression, and AdaBoostM1; also, the mean absolute error value was 0.05, and the FP rate value was 0.04.

In logistic regression, the correctly categorized examples were about 88%, which was much higher than the other classification approaches investigated, such as IBK and AdaBoostM1. Similarly, the accuracy, recall, and F-measure values of 0.88, 0.88, and 0.87 were greater in comparison to IBK and AdaBoostM1, as was the mean absolute error value of 0.05 and the FP rate value of 0.04.

Overall K-star is the best classification algorithm that can be used for task scheduling followed by Logistic Regression as in the majority of observations at different configuration settings the Accuracy, Precision, Recall, F-Measure, etc. are higher in case of algorithms mentioned above.

## 6.4 Classification Algorithms in Task Offloading and Resource Allocation

The results confirm that the MLP classifier has the best overall accuracy value 0.83, followed by the Logistic Regression value 0.80. The other classification methods had an overall accuracy of roughly 0.75 in the case of the J48 classifier, 0.60, 0.61, and 0.48 in the case of Bagging, IBK, and K-Star, respectively. MLP and Logistic Regression were discovered to be the best acceptable classifiers based on performance measure total accuracy. Comparing classifiers based on overall Kappa statistics used for task offloading and resource allocation in SMART FOG environment, MLP and Logistic Regression have higher overall Kappa statistics values of 0.67 and 0.6, respectively, indicating that they are superior classifiers.

MLP classifier has the best precision at 0.85, followed by Logistic Regression at 0.83. J48 had 0.79 Precision, Bagging 0.48, IBK 0.76, and K-Star 0.49. MLP and Logistic Regression were the most precise classifiers.

MLP classifier has the greatest recall overall with 0.84, followed by Logistic Regression with 0.80. Bagging, IBK, and K-Star had Recalls of 0.61, 0.62, and 0.49, respectively, while J48 had 0.75. MLP and Logistic Regression were the best classifiers for total Recall.

MLP classifier has the lowest mean absolute error value of 0.17, followed by Logistic Regression with 0.23. J48, Bagging, IBK, and K-Star had mean absolute error values of 0.27, 0.58, 0.39, and 0.45, respectively. MLP and Logistic Regression were the best classifiers based on performance metric mean absolute error value.

In conclusion, after examining each classification algorithm based on a variety of accuracy parameters, one can conclude that MLP and Logistic Regression are the classification algorithms that are best suited for resource allocation and task offloading.

## 6.5 Future Scope

In this section, the key issues, future difficulties, and future research prospects for task scheduling in fog computing are discussed.

**Resource Utilization of Fog Node**

The fog devices have limited storage, processing, and energy capabilities due to their lack of resources. They receive dynamic workloads from applications that are sensitive to latency as well as apps that are tolerant of delay. As a result, the difficult aspect is to schedule the unpredictability of the arrival of activities on these fog nodes to make the best possible use of the available resources.

**Optimal Resource Allocation**

IoT devices produce a large number of tasks, which have to be appropriately distributed between fog nodes to achieve a quicker reaction time. This is especially important for applications that are sensitive to latency. Since fog computing makes it possible for fog nodes and Internet of Things devices to move about freely, the resources that are reachable at any given time may be inaccessible at other times. Because of this, the process of allocating resources is a difficult endeavor. The problems that need to be addressed are long latency for real-time applications, a lack of generalization, and rapid adaptation of the algorithms that are currently available.

**Parallel Scheduling**

In the method known as parallel processing, one operation is broken down into several smaller tasks, all of which are then carried out at the same time. Another unresolved problem that requires attention is the division of activities into subtasks that can decrease delays through the use of distributed computing.

**Privacy**

Several different fog applications, such as smart healthcare, send a significant amount of personally identifiable information to fog nodes. As a result, protecting the confidentiality of such data is of the utmost importance to users. Even while some researchers use methods that protect users' privacy on fog nodes, there is yet no authentication solution that can be considered satisfactory. Because the fog nodes are more susceptible to possible dangers, authenticating users can be a difficult and time-consuming process.

**Security**

Fog nodes are vulnerable to attacks. As a result, developing a safety algorithm that is not only lightweight but also has a fast speed and is trustworthy is still a tough issue. At the moment, only a small number of academics are focusing their attention on the security concerns associated with fog computing; nonetheless, there are still several outstanding challenges, such as dynamic authentication, access controls, external threats, and intrusion detection.

**Context-aware Service Provisioning**

The context is made up of the many runtime elements that have the potential to influence the applications. The currently available approaches to context-aware service provisioning are less flexible and scalable, and they are unable to manage a significant number of Internet of Things applications. Because of this, more approaches to context-aware service delivery should be researched so that the aforementioned restrictions may be solved.

**Energy Consumption**

Energy-aware computing in fog is still an open question that has to be answered since fog devices are limited in their ability to use energy due to their usage of low-power batteries. Several academics are concentrating their efforts on energy optimization,

but several problems still need to be addressed, including improper utilization of bandwidth during data transfer, energy waste, and battery-draining concerns.

## 1.6 Limitations

Fog computing faces several limitations, including high latency compared to edge computing, increased complexity in network management, potential security vulnerabilities, and limited scalability. It can also suffer from resource constraints due to dependency on intermediate devices and challenges in data processing efficiency. Additionally, ensuring consistent connectivity and handling diverse data types can pose significant difficulties in fog computing environments.

1. Scope and Generalizability: The study may have focused on specific IoT architectures, protocols, and technologies, which might limit its generalizability to other IoT scenarios or environments.

2. Real-world Implementation Challenges: The study might not have addressed the practical challenges associated with implementing the SMART FOG protocol-based technique, such as hardware compatibility, software integration, security considerations, and deployment complexities.

3. Benchmarking and Comparison: The study might lack comprehensive benchmarking or comparison with existing IoT architectures, protocols, or alternative solutions. Comparative analysis would provide a better understanding of the advantages and limitations of the proposed SMART FOG approach.

4. Limited Testing Scenarios: The evaluation of the SMART FOG technique might have been conducted under specific testing scenarios or simulated environments, which may not fully capture the complexities and dynamics of real-world IoT deployments.

5. Time Constraints: The study might have faced time limitations, which could impact the depth of analysis, experimentation, and validation of the proposed techniques.

6. Lack of Real-world Deployment Validation: The proposed SMART FOG technique might not have been validated in real-world IoT deployments or scenarios, which may limit the assessment of its practical applicability and performance.

In conclusion, fog computing's limitations include potential latency issues, increased network complexity, and security vulnerabilities. It also faces scalability challenges, resource constraints from intermediary devices, and inefficiencies in data processing.

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# APPENDIX

# Appendix: List of Publications and Conferences Attended

1) Suraj Rajaram Nalawade, Dr. Ashok Kumar Jetawat, "Use of Clustering Machine Learning Algorithms in Fog Computing for Task Scheduling and Resource Allocation" has been published in European Chemical Bulletin (ISSN: 2063-5346), Volume 11, Issue 8, 2022 Date of Publication: - August 2022.

2) Suraj Rajaram Nalawade, Dr. Ashok Kumar Jetawat, "A Comparative Study of Various Classification Machine Learning Algorithms in Fog Computing: Task Scheduling" has been published in Industrial Engineering Journal (ISSN 0970-2555), Volume: 52, Issue 5, No. UGC Care Approved, Group I, Peer Reviewed Journal 4, May: 2023.

3) "The Survey on Fog Computing and its Applications" International Virtual Conference on "Emerging Era of Applications of Computer, 15th -16th of January 2022 Organized by Pacific University Udaipur.

4) National Seminar on "Implementation of Academic Bank of Credit (ABC) in Higher Education Institutes" on 21st March 2023 Organized by Avinashilingam Institute for Home Science and Higher Education for Women University Udaipur.

5) IP Awareness Training Program under "National Intellectual Property Awareness Mission" Organized by Intellectual Property Office, India on 18, January 2023.