CHAPTER V
CONCLUSION AND SUGGESTIONS

5.1 Conclusion

Based on the design, implementation, and evaluation results of the adaptive bandwidth management system based on Sugeno Fuzzy Logic and Per Connection Queue (PCQ) in the SCR Laboratory network of UPN "Veteran" Jawa Timur, the following conclusions can be drawn:

1. The adaptive bandwidth management system was successfully designed using a closed-loop control mechanism that integrates Sugeno Fuzzy Logic and Per Connection Queue (PCQ). The system operates by classifying network traffic into three priority classes Real-time, Streaming, and Bulk. Through the processing of two input variables, namely the number of active clients and network traffic load, using nine fuzzy inference rules, the system is capable of generating dynamic pcq-rate allocation values according to current network conditions.
2. The proposed system was successfully implemented as an autonomous solution using a Python-based application integrated directly with a MikroTik router through the RouterOS API. The system operates in a near real-time manner with a monitoring interval of 10 seconds, enabling it to continuously monitor network conditions, perform fuzzy computations, and automatically update bandwidth allocations in response to traffic fluctuations without requiring manual administrator intervention.
3. The system proved effective in providing fair and proportional bandwidth distribution while maintaining the predefined service-priority hierarchy under fluctuating network traffic conditions. In terms of Quality of Service (QoS) performance based on the TIPHON standard, the system improved the throughput index from the Fair (2) category to the Very Good (4) category under moderate traffic conditions. Furthermore, it consistently maintained packet loss, delay, and jitter within the Very Good (4) category across all testing scenarios, indicating that adaptive bandwidth allocation can be achieved without degrading overall network performance.

5.2 Suggestions

Based on the findings of this study, several recommendations can be proposed for future research on adaptive bandwidth management systems:

1. In this study, the Sugeno Fuzzy rule base and the pcq-rate output values were determined manually based on predefined configuration parameters. Future studies may develop a more dynamic approach by integrating an Adaptive Neuro Fuzzy Inference System (ANFIS) and incorporating real-time available bandwidth as an additional decision parameter. Such an approach could enable the system to automatically update its inference rules and produce bandwidth allocations that more accurately adapt to changes in network capacity.
2. Future research may extend the implementation of adaptive bandwidth management systems to a Software Defined Networking (SDN) environment. The SDN architecture separates the control plane from the data plane, allowing bandwidth management decisions to be centralized through an SDN controller. Integrating Sugeno Fuzzy Logic with SDN has the potential to improve network flexibility, scalability, and manageability, particularly in large-scale and complex network infrastructures.
3. The performance evaluation conducted in this study was limited to a controlled laboratory environment and the hardware specifications available during testing. Future studies are encouraged to investigate the scalability of the proposed system in larger and more complex environments, such as campus or enterprise networks. In addition, Quality of Service (QoS) evaluation can be enhanced through the use of network devices that support packet sniffing or port mirroring, enabling more comprehensive performance measurements across multiple active clients simultaneously.