Chapter 6

Conclusion and future work

This chapter recaps the context of the thesis, summarizes the essential contributions of this research work, and, in the end, outlines the direction of future research towards the advancement of IoT applications using machine learning in various other areas.

Conclusion

This work has considered various problems and challenges with the advancement of IoT applications using machine learning. The main objective of this thesis was to create efficient, effective, and secure long-range communication in smart IoT applications. This work focuses mainly on two tasks, i.e. solving imperfect labels in federated learning in intelligent transportation systems based on LoRa communication and interference communication in the LoRa network. While distributed training model in the federated learning environment. While training the model for locomotion modes recognition, we face the problem of imperfect label data in federated learning using LoRa communication protocol. We also solve interference problems based on Signal noise ratio(SNR) in LoRa networks in smart building applications. Federated learning-based IoT application is robust and secure and also improve bandwidth utilization. These problems are common and frequently occur in IoT applications in the distributed training learning environment. This thesis emphasized three major research contributions and one research enlist challenge in agriculture from an IoT perspective.

In chapter 3, This work covers Fed-LoRa, a federated learning approach for Intelligent Transportation Systems (ITS). This work aims to improve data security and communication efficiency while handling the issue of imperfect label data in participant device datasets. The ITS application, which collects a substantial amount of transportation data, encounters challenges in remotely sharing this data for machine learning. For efficient data transmission, fed-LoRa is considered a Long-Range Wide Area Network (LoRaWAN).LoRaWAN is LPWAN type techniques.In this paper, we have estimated class-wise centroids to identify participants with imperfect labels and use data reduction and inclusion mechanisms to enhance their performance. Fed-LoRa employs a Long-Range Wide Area Network (LoRaWAN) for efficient data transmission, estimates class-wise centroids to identify participants with imperfect labels, and uses data reduction and inclusion mechanisms to improve their performance.An appropriate fraction of the server dataset is calculated to minimize the influence of imperfect labels. The experimental validation proves Fed-LoRa's effectiveness in protecting privacy, security, and communication efficiency in the setting of ITS. Finally, the experimental results depicted the proposed approach effectively performed on a publicly available dataset of transportation modes.

In chapter 4, We covered the second problem of identifying the interference nodes in LoRa networks. Our approach utilizes machine learning techniques, using SNR and RSSI values to identify nodes that cause network interference accurately. We conducted experiments in different deployment scenarios, including a high-ceiling smart building, and observed that network parameter-based interference solutions work well in scenarios with few obstacles and static LNs and LG. Our approach successfully estimates interference from up to five devices on a given SF with high accuracy. We also observed that interference among LNs with low SF is higher, likely due to the proximity of all devices to each other and the LG. Our method is cost-effective as it is hardware-independent, making it feasible to implement on the LG platform. Finally, we present a dataset of network interference generated by varying the number of nodes, obstacles, and other parameters. We train the model on the generated dataset and evaluate its effectiveness using a test bed. The experimental results demonstrate that the approach can successfully identify interference nodes in a complex network.

In chapter 5, This paper proposed an approach to enhance the lifetime of UAV-enabled aerial networks via AIoT. The main objective of the EU-AIoT approach is to improve the lifetime of aerial networks by replacing DNN on battery-operated UAVs with lighter versions, incurring minimal accuracy compromise. EU-AIoT has used optimal dropout selection followed by weight factorization and reducing gated units to obtain lightweight. DNN from given large-size DNN satisfying constraints battery power, memory, and task frequency. We further utilized the concept of knowledge distillation, where we adopted layer sharing among teachers and students, followed by selective back-propagation of shared layers during student training. We finally carried out various experiments to validate the effectiveness of the EU-AIoT approach. We next present a knowledge distillation-based approach, which reduces training time and enhances accuracy. Finally, we evaluate the approach on the existing dataset. This work provides a future direction toward developing a DNN compression technique for more versatile applications utilizing UAVs during disasters.

This thesis work can be applied in many smart applications:

- Autonomous Vehicle Navigation:
- Smart Parking Systems:
- Fleet Tracking and Logistics
- Environmental Monitoring and Smart Infrastructure
- Personalized Health Monitoring
- Smart Homes
- Recommendation Systems

Future Directions

This work has made contributions towards the investigation of the different challenges encountered while the Advancement of IoT applications using machine learning for applications in smart IoT devices. The primary objective is to mitigate the negative impact of Imperfect Labels in LoRa-based Transportation Systems and LoRa network Interference problems in the long-range and distributed learning techniques. Further, we introduced different techniques to successfully advancement of IoT applications using machine learning. It mitigates the LoRa network interface problem in a long-range communication application. We also enhance data security and reduce bandwidth consumption in distributed learning using federated learning. By using these results in our thesis, one can effectively handle the challenges of distributed learning and long-range communication. The proposed work would motivate further research towards effectively implementing the unseen potential of distributed learning in long-range applications. This thesis also provides direction for using distributed learning techniques and long-range communication to adapt to different dimensions and challenges to develop user-friendly IoT devices. The thesis expressed here can be further extended in the following manners:

- This work provided the technique to handle imperfect label issues in the federated learning environment. There is still scope to implement imperfect label techniques in network traffic classification in the federated learning environment.
- This work covers interference problems in long-range communication using the LoRa network. There is still scope for parameter optimization in the LoRa net-

work in the distributed learning environment.

- We emphasize that the proposed work motivates further research in combining federated learning and differential privacy techniques to make the device more robust from a security point of view.
- We are focusing on designing resource-constrained hardware to implement federated learning on individual IoT devices that are small in size. We also plan to use a few shot-learning concepts to consider the imbalanced dataset while training a model in the federated learning environment.