CHAPTER 1
INTRODUCTION

1.1 Background

The Fifth Generation of mobile communication, commonly known as 5G, is a new mobile communication system with higher speeds, less energy consumption, and lower latency than previous-generation technologies. Device-to-Device (D2D) communication is one of the key technologies to achieve these goals, and it is considered an essential role in 5G. D2D communication is direct link communication between two communication devices, meaning that communication can occur without going through the base station. D2D communication technology has many advantages. D2D communication can reduce communication delays and improve spectral efficiency, energy efficiency, and throughput [1]. However, because communication occurs without going through the base station and D2D users do not have their resources, D2D users simultaneously use the resources owned by Cellular User Equipment (CUE) to communicate and cause interference. To overcome this, power allocation has become an important technology for solving interference problems [2].

In wireless networks, power allocation is an effective technique for prolonging the lifetime of network terminals. Generally, optimum power allocation improves the efficiency of wireless systems [3]. In D2D communication, the power allocation is optimized to mitigate the interference between D2D users and cellular users and further maximize the system's overall throughput [4]. However, the problem of power allocations is formulated as a non-convex mixed-integer non-linear programming (MINLP) problem, where each D2D pair can reuse the channel of at most one CUE and each CUE can share their resources with at most one D2D pair. To overcome this, Convex Approximation (CA) based algorithm is implemented to approximately convert the non-convex MINLP optimization objective into a convex one [5].

In [6], power allocation optimization problems are solved iteratively by utilizing iterative schemes with conventional method,such as Convex Approximation (CA) based algorithm. This conventional technique employs many Transmission Time Interval (TTI), impacting performance if the system requires a real-time operation. Because of the limitations of traditional methods for operating in real-time systems, machine learning has emerged as the most appropriate way to overcome the limitations of real-time operation [7].

Because of the limitations of traditional methods for operating in real-time systems, Deep learning (DL) has become a popular topic in various fields due to its significant advantages over conventional approaches. DL can handle large amounts of data, and DL algorithms are scalable with increasing data, benefiting model training and improving prediction accuracy. DL also reduces the computational and time complexity as a single trained model and can be used for various tasks and achieve multiple objectives without model retraining [8]. Alternative methods by treating the time series forecasting problems as general regression with time-varying parameters were applied by deep learning models, e.g., Long Short-Term Memory Fully Convolutional Network (LSTM-FCN) model [9]. This model is capable of including complex non-linearity dependences of large multivariate datasets. LSTM-FCN is believed to reduce computation time and work well in many situations. Several studies have been carried out using the LSTM-FCN model, but no research has been used in D2D communication.

This thesis aims to design the LSTM-FCN model suitable for the transmit power control problem in the cellular network on an underlay D2D communication system with an uplink-side and multi-cell scheme. Power allocation is carried out in a multi-cell D2D communication system because multi-cell communication can make two devices in different cells communicate.

1.2 Problems Definition

The main problem in underlaying D2D communication is utilizing the same resource for several devices, causing interference and affecting the overall system performance. Power allocation is used to overcome the problem of D2D underlaying communication system interference.

The problem formulation in this study is as follows.

1. The D2D communication system in a multi-cell scheme makes communication between devices possible by devices in the same cell and different cells. It can cause intercell and intracell interference problems.
2. The ability of the LSTM-FCN model to approximate the CA-based algorithm method to generate power control policies.
3. Performance of the LSTM-FCN model in terms of system sum rate, system power consumption, system energy efficiency, computational time, and time complexity.

1.3 Related Research

In [10], an LSTM-based strategy is proposed based on time series forecasts enabled by deep learning and weighted exponential averages. The interference prediction module installed in every d2d user predicts the interference level to select the best available channel. The efficacy of the proposed solution is established through numerical results in terms of system reliability, packet error rate, and normalized mean square error. The system reliability is improved by 4.6% while reducing the packet error rate by 15.2% for 62.5% fewer prediction errors. However, system reliability decreases with an increase in the D2D radius for each resource selection scheme.

In [11], a recurrent neural network framework (long-short term memory or LSTM) is used, which is used to effectively predict and model the stochastic nature of communication costs and user file access patterns to solve caching problems in D2D communications. The performance of the frameworks in different settings shows that the proposed caching scheme can outperform the classic and recent frameworks by about 10% to 25%. However, there is a lower increase in vDNN traffic release.

In [12], Reconfigurable Intelligent Surface-enabled downlink spatial multiplexing using a fully convolutional network (FCN) is used and achieves higher performance and shows faster evaluation speed than the baselines. Besides that, it can maximize the weighted sum rate (WSR). In the evaluation, they obtained a WSR of 6.87 bit/s/Hz. Compared to the WSR at the end of training (7.26 bit/s/Hz), the WSR in the evaluation is roughly 5% less than the WSR in training, which suggests a low overfitting level and a suitable generalization of the trained model. However, finding a criterion to optimally decide which users are selected to share the same resource block is desirable, which can significantly improve the average performance.

In [13], the LSTM-FCN model is used to improve FCN performance with a nominal increase in model size and requires minimal initial processing of data sets to be used for time series classification. LSTM-FCNs can augment FCN models, appreciably increasing their performance with a nominal increase in the number of parameters. When refinement was applied, the MPCE of the LSTM-FCN models was reduced by 0.0035. Refinement improves the accuracy of the LSTM-FCN models, but it requires more training time due to the added computational complexity of retraining the model using smaller batch sizes.

In [14], the applicability of more complex dual-flow DL methods, such as long short-term memory fully convolutional network (LSTM-FCN), is analyzed and compared with vanilla single-flow convolutional neural network (CNN) models for the host-level intrusion and malware detection. The results obtained are tested models were able to reach 90% accuracy with as little as 20 system calls and had practically applicable accuracy of 98% with a sequence of 600 system calls. However, dual-flow LSTM-FCN and GRU-FCN state-of-the-art models must be used to achieve more efficient tests on many datasets.

Several studies have been carried out using the LSTM and FCN algorithms and have improved system performance on D2D underlaying. However, no research combines the two algorithms and uses them in D2D communication. Therefore, this final project aims to design and compare these two algorithms with the FCN and LSTM algorithms.

1.4 Research Purposes

This thesis aims to design an LSTM-FCN model to approach CA-based algorithm performance to produce power control policies and solve the interference problem using a power allocation scheme in the D2D multi-cell underlaying communication system. The model is evaluated and its performance analyzed in terms of system sum rate, power consumption, energy efficiency, computational time, and time complexity.

1.5 Scope of Work

The goal of this thesis is to provide an power allocation scheme in a D2D underlay with a multi-cell cellular network. The following are some of the research areas pursued::

1. Long Short Term Memory with Fully Convolutional Network is used to make a power control scheme in the D2D underlay with a multi-cell cellular network.
2. The suggested power allocation algorithm is putted corresponding with the following specifications:
   - Multi-cell system, fixed user, and no handover.
   - Applied in uplink.
   - The uplink resource block has been orthogonally preassigned to all CUE, ensuring that the signal between CUE does not interfere with the others CUE.
   - Resources owned by CUE can be utilized by several D2D pairs.
   - The power control management is focused on D2D and CUE side.
3. The proposed method is compared to CA-based algorithm as the benchmark. Beside that, the proposed method's performance is compared to the FCN and LSTM algorithm.

1.6 Research Methodology

The research methodology on this works are divided into several steps and can be clarified through Figure 1.1, they are :

1. Literature Study

   The identification of related problems is carried out through a literature study. Literature studies are taken from the latest research results, such as journal papers, international conference papers, and books related to this research topic. Based on several works of literature, a D2D communication scheme in a single cell with LSTM or FCN algorithm can achieve higher performances than conventional optimization methods.
2. System environment design

   After getting enough references from the literature study results, a system modeling becomes the research environment and problem formulation related to this research. The system is modeled with a D2D underlay communication scenario on a multi-cell for the uplink side. In this model, CUE and D2D users are spread around the cell, and the user is assumed to be in a stationary state to avoid handover.

3. Algorithm design

   After the system environment has been created successfully, a programming algorithm is written which initializes each parameter to be used and allocate powers using the LSTM-FCN algorithm. The dataset used in this thesis consists of channel gain from all communication links as input and power control policies obtained through Convex Approximation (CA) based algorithm.

4. Simulation process

   The algorithm that has been created is converted into a programming language compatible with the simulation software and then tested and recorded on the analysis of the simulation results obtained. The simulation uses two scenarios: enhancement of CUE and enhancement of D2D pair. The number of users is increased from 2 to 6 users per scenario.

5. Results analysis

   The simulation process produces actual power allocation policies and is used to calculate system performance. The performance is reviewed in terms of system sum rate, power consumption, energy efficiency, computational time, and time complexity. The CA-based algorithm is used as the benchmark to test the performance of the LSTM-FCN model. The proposed algorithm's performance is compared to the FCN and LSTM algorithm.

6. Conclusion

   The analysis data from the simulation results is used to answer the problems and questions in the research.

1.7 Thesis Structure

This thesis is compiled and written based on the following writing system, which is divided into five chapters, namely:

CHAPTER 1 INTRODUCTION

This chapter contains background problems, problem definition, related research, research purposes, the scope of work, research methodology, and thesis structure.

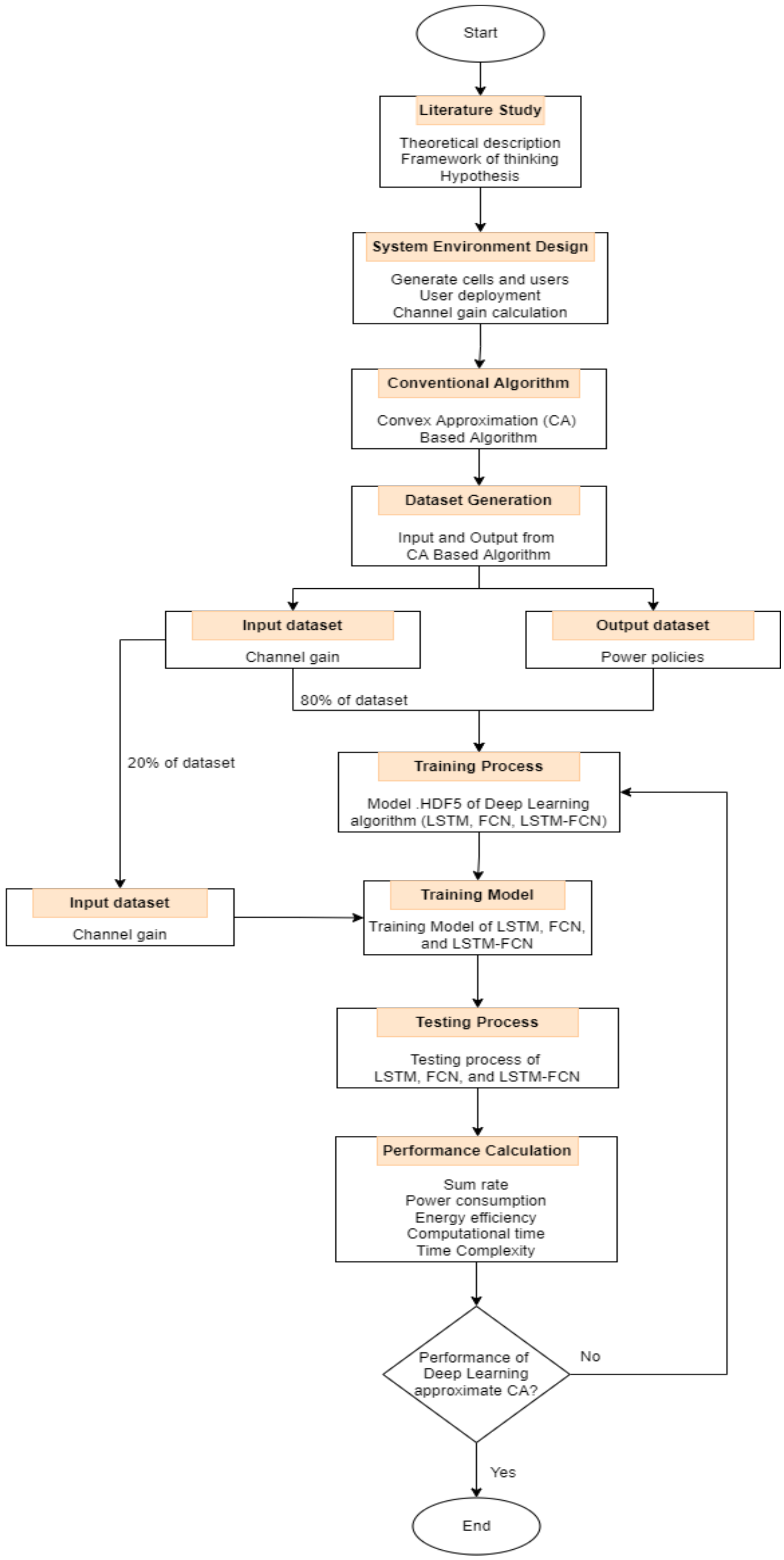

FIGURE 1.1: Reseach methodology.

CHAPTER 2 REVIEW OF LITERATURE AND STUDIES

This chapter contains the theoretical basis that supports or relates to the writing of this final project which consists of four sub-chapters with basic and detailed discussions.

CHAPTER 3 SYSTEM MODELLING

This chapter contains the research flow, system model and simulation scheme to be carried out.

CHAPTER 4 RESULT AND ANALYSIS

This chapter contains the results of the simulations carried out and an analysis of the results obtained.

CHAPTER 5 CONCLUSION AND FUTURE RESEARCH

This chapter contains conclusions from the simulation results that have been carried out and suggestions for further research.