CHAPTER 1
INTRODUCTION

1.1 Background

5G technology is one of the cellular technologies that was just released in 2021 in Indonesia, where this technology requires speed, coverage, and network reliability. There are three key technologies in 5G, namely Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC), and Ultra-Reliable Low Latency Communications (URLLC). Device to Device (D2D) communication systems is a part of mMTC. D2D communication systems reduce the workload of the base station and increase network capacity and spectrum efficiency. This is because in this communication system devices can communicate directly without going through the base station [1]. Therefore, this communication is used as public safety network when there is damage to the base station while a disaster. Besides that, D2D user devices will also be useful in the development of the Internet of Things (IoT), where the devices will be connected and able to communicate with each other. For example, sensors that are interconnected exchange data and can make decisions automatically [2].

Operating spectrums that are used in the D2D communication system are unlicenced spectrum (outband) and licensed spectrum (inband). The majority of the research is focused on the licensed spectrum as it provides a higher level of security [3]. In the inband spectrum, there are overlay and underlay communication systems. This thesis uses an inband underlying communication system where D2D pairs reuse the spectrum of Cellular User Equipment (CUE) by using the resource of CUE simultaneously. But the resources that are used simultaneously by the D2D pair and CUE, cause interference to occur. The interference should be solved by power allocation. The power allocation also can maximize the energy efficiency of the system. Energy efficiency is important in D2D communication systems because there is a limited power of devices such as batteries [4].

In a D2D multi-cell communication system, several users use the channel simultaneously and causing multi-user interference. This results in non-convex optimization problems while maximizing sum-rate and energy efficiency. To solve the non-convex problem, a Convex Approximation (CA) based algorithm is used. This algorithm is

also used for power control to allocate transmit power of each user. The process of this algorithm uses the Dinkelbach and Condensation technique. This algorithm causes high computational time and time complexity problems because of the utilized iterative schemes. Besides that, this algorithm also can not be applied in real-time conditions.

Deep Neural Network (DNN) is part of artificial intelligence. DNN is a deep learning technique based on a neural network that works like neuron activity in the brain of a human. DNN can be used for power allocation replacing conventional schemes based on mathematical models because DNN works by taking a learning-based approach [5]. Besides that, DNN can be considered a universal approach that can determine the best scheme in the system because it can adapt to different environments. The use of DNN can also reduce computational time compared to conventional schemes because DNN only performs simple matrix operations.

This thesis performs resource and power allocation in a D2D multi-cell underlying communication system using the DNN technique. Resource and power allocation is carried out in a D2D multi-cell underlying communication system because, in the multi-cell communication system, two devices not only can communicate with the device in the same cell but also can communicate with the device in different cells. Resource and power allocation are done using DNN techniques to approach the performance of CA-based algorithm. DNN used to overcome non-convex problems, maximize the energy efficiency of the system, and reduce complexity and computational time. In this thesis, the performance of the system will be seen based on an increment in the number of CUEs and D2D pairs. The performance consists of sum-rate, power consumption, energy efficiency, and computational time. Besides that, the time complexity of each algorithm, and the impact of the number of the dataset to Mean Square Error (MSE) will be seen.

1.2 Problems Definition

Based on the research background, the problem in the D2D multi-cell underlying communication system is the interferences problem that needs to be overcome by resources and power allocation. The problem definition in this thesis are as follows:

1. The D2D multi-cell underlying communication system makes communication between devices not only possible by the devices that are in the same cell, but also by devices that are in different cells. It causes intercell and intracell interference problems
2. CA-based algorithms can be used as power allocation to solve the non-convex

problem and maximize the energy efficiency of the system, but there is a complexity and computational time issue, so this algorithm can not be applied in real-time conditions

3. The number of CUEs and D2D pairs affects the performance of the system
4. The number of datasets used in the training process affects the MSE of the model.

1.3 Related Research

Research [6] conducted resource allocation using conventional schemes through approaches and assumptions based on mathematical models. This scheme iteratively allocates resources using a joint greedy algorithm and a water-filling power control scheme to improve energy efficiency, where the transmit power of each user is adjusted according to channel conditions. This scheme increase energy efficiency. Research [7] proposes a spectrum resource management algorithm and a distributed power optimization scheme. The process consists of the dual Lagrangian reconstruction and the quadratic transformation to transform mixed integer nonlinear programming (MINLP) into a convex problem. The simulation results that the proposed scheme and algorithm could significantly improve the system throughput and D2D user access rate in the dense deployment case. Research [8] investigated the joint uplink and downlink resource allocation for NOMA-enabled D2D communications using the subcarrier assignment algorithm. Besides that, an iterative power allocation algorithm of D2D pairs by the sequential convex approximation was also used. The simulation results that the efficiency of the algorithm in maximizing the sum-rate. Research [6–8] results in a good performance, but the complexity and computational time are high because of the iterative step and cannot be used in different environments or real-time conditions.

Research [9] conducted resource allocation on multi-channel underlay cognitive radio using DNN and increased spectral efficiency by maintaining interference below the threshold. In research [10], resource allocation is carried out using a deep learning-based power control scheme on an overlay D2D communication system. This study resulted in better energy efficiency than the Weighted Minimum Mean Square Error (WMMSE) scheme even when using a small feedback Channel State Information (CSI) value. In research [11], resource allocation was carried out on a multi-cell D2D communication system using Deep Reinforcement Learning, and resulted in lower energy efficiency than the exhausting search method.

In research [5], resource allocation is carried out on a single cell D2D communication system using a DNN scheme. This research resulted in an energy efficiency of 96.6% and a low computation time. Research [12] conducted power allocation for NOMA-based

relay-assisted D2D system using a deep neural network. The training data of DNN based algorithm is generated through a convex optimization-based scheme. The simulation results that the DNN provides optimal performance with low time complexity. The low complexity of DNN makes the system can be applied in real-time conditions.

Based on the related research above, this thesis will provide resources and power allocation in a D2D multi-cell underlying communication system using the DNN to approach the performance of the CA-based algorithm with low complexity and computational time, so the algorithm can be applied in real-time conditions.

1.4 Research Objective

Based on the existing problem formulation, the objectives of this thesis are as follows:

1. Perform resource and power allocation in D2D multi-cell underlying communication systems to reduce intracell and intercell interference in maximizing the energy efficiency of the system.
2. Applying resource and power allocation in D2D multi-cell underlying communication systems using DNN techniques to approach the performance of the CA-based algorithm so that it can be applied in real-time conditions because reduces complexity and computational time.
3. To see the effect of increasing the number of CUEs and D2D pairs on sum-rate, power consumption, energy efficiency, and computational time in D2D multi-cell underlying communication systems.
4. To see the effect of increasing the number of datasets on MSE.

1.5 Scope of Work

This thesis aims to perform a good performance in a D2D multi-cell communication system using DNN to approach the CA-based algorithm. Several steps that will be pursued are:

1. DNN is used for resource and power allocation to maximize energy efficiency in D2D multi-cell underlying communication systems.
2. The proposed method is compared to the CA-based algorithm as the benchmark.
3. Simulate the DNN in D2D multi-cell underlying communication systems with the following specifications:
    - The system is multi-cell which consists of two cells
    - Applied in the uplink direction
    - The user is stationary to avoid handover occurs
    - The power allocation is focused on the CUE and D2D side

- CUE resource can be used by several D2D pairs
- The increased number of users in the first scenario is from two to six users and in the second scenario is from two to twelve users.

1.6 Research Methodology

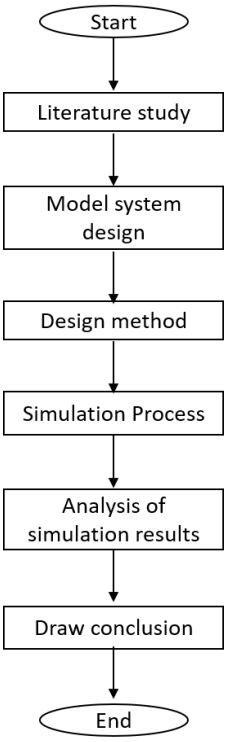

FIGURE 1.1: Research Methodology

The research methodology in this work is divided into several steps, they are :

1. Literature study

   Problem identification is carried out through literature studies from the latest research results in the form of journals and papers related to research topics such as resource and power allocation in D2D underlying communication systems and the application of DNN techniques.

2. Model system design

   At this stage the system model that will be used and problem formulation is designed. The system model designed in this research is a D2D multi-cell underlying communication system with the uplink transmission direction. In this model, users consisting of CUE and D2D pairs are spread around the cell and the user is stationary.

3. Design method

At this stage the resource allocation process is carried out using DNN. There are 150,000 datasets used which consist of channel gain as the input and power allocation policies as the output to maximize the energy efficiency of the system.

4. Simulation process

   At this stage the simulation is carried out by conducting data training and applying DNN to allocate resources and power allocation of each user to maximize the performance of the system. The CA-based algorithm is used as the benchmark of DNN performance.

5. Analysis of simulation results

   At this stage the simulation results obtained were analyzed. The accuracy of DNN and CA-based algorithm performance and the impact of the increment in the number of users are seen. Besides that, the complexity of each algorithm, and the impact of the increased number of datasets on MSE is also seen.

6. Draw conclusion

   At this stage, conclusions are drawn based on simulations and analysis results.