Interference Mitigation Strategy for D2D Communication in 5G Networks

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ABSTRACT

Device-to-Device (D2D) communication is one of the most promising developments in 5G networks. D2D communication can reduce communication latency and increase spectrum efficiency and system capacity. However, implementing D2D communication in reuse mode with a traditional cellular network can result in severe interference that can significantly reduce network performance, as both networks share the same resources. It is essential to mitigate interference to improve network capacity when D2D communication coexists with traditional cellular networks. An effective power control strategy can help mitigate the potential detrimental impact of interference and maximize the potential benefits of D2D communication. In this study, a dynamic transmission power control strategy was proposed for D2D transmitters to allow them to dynamically adjust transmission power, aiming to minimize interference and maximize network capacity. The distance between and the number of D2D pairs that experience interference were the primary parameters considered for the proposed strategy, while its complexity was in polynomial time. A simulation was carried out to evaluate the proposed strategy and compare it with fixed and ranged-based approaches, and the results validated its effectiveness.

Keywords-5G; D2D; interference; power control

I. INTRODUCTION

All wireless communication systems have shown impressive improvements during the past few decades. However, the increasing demand for communication services is not being met by the current state of wireless network improvement. The demand for ubiquitous high-speed Internet access and the increase in the average number of connections per user have led to meteoric development in all these metrics for today's wireless communication systems. Additionally, current wireless systems are not equipped to handle the increasing demand for hyperrealistic multimedia services, such as those used in vehicle-to-vehicle, wireless health applications, virtual reality, and Internet of Things (IoT) applications, and the use of wireless networks as essential broadband access service [1]. Mobile traffic is expected to expand at an annual rate of about 55% in 2024-2030 [2], which is a huge demand in terms of network resources and link capacity. Moreover, effective management of limited resources is required to keep up with this growing demand. Existing wireless network systems might not be able to handle the explosive growth in demand that future wireless network applications will require.

According to recent developments, a new 5G network design is required to address spectrum challenges and satisfy customers' demands for high-speed connectivity. Increased mobile data volumes, lower latency, huge network connectivity, and stable experience quality are all necessary for the 5G wireless network to provide seamless user experiences. Several essential technologies have been proposed to enable the 5G network to achieve these goals. Technologies include massive Multiple-Input Multiple-Output (MIMO), Device-to-Device (D2D), millimeter wave (mm-wave), and Ultra-Dense Network (UDN). D2D communication is considered a promising technology for 5G networks, as it allows nearby devices to be directly connected without going through the main base station. In addition, D2D communications can reuse cellular resources [3-6]. D2D communication can be used as an underlying layer in cellular networks to support communication between nodes that are adjacent to each other with minimal latency and energy consumption. In addition, D2D communications would be implemented to offload traffic from Macrocell BS, which is the fundamental driver to implement them. D2D technology has great potential to facilitate proximity-based applications, as proximity between connected devices improves spectrum utilization and supports the power efficiency of cellular networks [7-9].

The D2D communication procedure consists of the discovery and communication stages. In the D2D discovery stage, D2D helps User Equipment (UE) to find nearby devices that might be able to communicate directly with it. In the communication stage, newly discovered D2D users set up communication channels to share information. Procedures for establishing a connection between two or more D2D users in proximity are what this stage is all about. Managing the interference introduced by the D2D transmitter and maximizing the efficiency of the UE power consumption have become essential requirements for the implementation of D2D communication [10]. This is the case despite the many advantages that D2D communications offer, which function in the underlay mode. For example, cellular links have to deal with cross-tier interference from D2D transmissions. D2D links should deal with interference between D2D transmissions, but also with interference between cellular links and D2D transmissions. The interference problem could be solved by multiple approaches. The Power Control approach is an essential method that can be used by cellular networks to regulate interference, protect Cellular User Equipment (CUE), and provide communications that minimize power usage [11-13]. Cellular networks that support D2D communications are susceptible to interference on both types: co-tier and cross-tier. Co-tier refers to the interference between D2D pairs that share the same resources, while cross-tier refers to the interference between D2D and cellular users in the same channel. Cross-tier interference occurs when the resource that is allocated to a user of the cellular network is reused by one or more users of the D2D network. Two types of interference occur when D2D communication coexists with conventional cellular networks:

- D2D-to-cellular interference: Depending on the direction of transmission, interference from D2D communication can occur at either the base station or the CUEs. In the uplink direction, the interference is received by the base station while it receives data from its CUE. In the downlink direction, CUE experiences interference from the D2D transmitter while receiving data from the Macrocell BS.
- Cellular-to-D2D interference: The direction of communication can also play a role in interference between cellular and D2D networks. The CUE that transmits to the base station is the source of interference to the D2D receiver in terms of the uplink transmission mode. In the downlink direction, the Macrocell BS would be the source of interference for the D2D receiver. Furthermore, undesirable mutual interference would be experienced when multiple D2D pairs compete for the same resource. D2D users in different pairings will always experience interference from each other, regardless of the direction of the transmission mode.

Sharing the same spectrum introduces the problem of interference. There are two main strategies for allocating the spectrum for D2D communication: in-band and out-band [14]. In the in-band strategy, the same licensed spectrum is shared between D2D and cellular communication. In the out-band strategy, D2D communication uses an unlicensed spectrum. The coexistence of cellular networks and D2D communication imposes the networks' elements to use the same frequency band. As a result, the problem of interference arises. Thus, a power control strategy is needed to solve this problem [15]. Moreover, the power control strategy could improve the use of the UE battery, as this issue has become an active research topic in the industry and academic community [16-17].

This study focused on the power control issue of D2D communication, to autonomously control transmission power. The D2D transmitter should be able to dynamically adjust its power to mitigate the undesirable impact of interference and improve network capacity.

II. RELATED WORKS

Power control is recognized as a promising strategy that can be used to mitigate interference. The geometric water-filing method was used in [18] to control the transmission power of the D2D transmitter. The proposed mechanism also included a resource allocation algorithm to distribute subcarriers among UEs, assuming that the transmission power is infinite, where in reality the batteries of UEs need to be recharged, so the transmission power is finite. In [19], two stochastic geometry-based power control algorithms were developed for interference coordination in underlaid D2D cellular networks, aiming to provide effective power control and showing that it was possible to increase the total capacity of the network. However, interference could not be canceled but can have an acceptable impact while still accounting for uplink transmission channels in a hybrid random network. In [20], an innovative power control strategy was presented for dense cellular networks operating in a frequency reuse strategy. This technique relied on setting the transmission power of D2D devices to reduce the interference they could cause. This study was conducted using a single scenario, and the findings suggested that introducing D2D communication into cellular networks could improve system capacity. In [21], a resource-sharing mechanism was proposed for channel assignment and power distribution in a downlink scenario for D2D communication, without affecting the quality of service. Each pair of D2D reused multiple channels from a variety of CUEs, and multiple pairs of D2D could share the same channels that were used by a single CUE. The Lagrangian dual optimization method was used to assign channels with appropriate power transmission for each assigned channel to increase the overall data rate of D2D pairs to its maximum potential.

The effectiveness of D2D communication for an uplink transmission mode in an underlay mm-wave-based technology was discussed in [22]. The mm-wave spectrum was responsible for a significant amount of interference and led to an attenuation of the user's signal due to path loss. Maintaining transmission power between predetermined higher and lower limits, the suggested power control method guaranteed the highest possible throughput, and the reduced outage probability of the proposed approach ensured greater performance, as it enabled D2D communication in the 5G mm-wave network. In [23], a dynamic power control strategy was proposed to reduce interference and improve network performance, improving overall system throughput with consistent and dynamic power regulations that considered channel conditions. In [24], a power control mechanism for smart grids was presented, which could incorporate contemporary communication technologies with issues related to power supply management. The results of the suggested scheme demonstrated superior performance compared to similar current schemes. In [25], graph theory was used to optimize resource allocation, aiming to increase ergodic sum rates. The bipartite graph was constructed according to the required outage probability constraints, and the Hungarian algorithm was used to identify the best solution. The simulation results showed an improved constrained spectrum efficiency of D2D pairs. However, the complexity of the proposed algorithm was high.

An overlapping coalition game scheme was proposed in [26], where each DUE could reuse several Resource Blocks (RBs), and numerous DUEs could share a single spectrum. In addition, the proposed method ensured the security of the entire system and increased performance by increasing the system sum rate to its maximum. In [27], power optimization systems were proposed to coordinate interference between communication channels, prioritize cellular communication, and set a maximum data rate for each link. Performance evaluations showed a considerable increase in data rates after taking into account all factors. In [28], a technique was presented to optimize power management in 5G IoT networks. The experimental results showed that the proposed strategy performed well in terms of accurately predicting battery life and maintaining a specific degree of network connectivity. In addition, an effective channel selection and power allocation strategy was proposed in [29] to reduce D2D-to-cellular interference. Furthermore, it increased the spectral efficiency in scenarios where each D2D pair could reuse numerous cellular subcarriers. The optimal power of the D2D user was calculated using the Lagrangian approach to optimize the D2D data rates, as well as to maintain the quality of service for the cellular user. Furthermore, this study explored how the location and distance between D2D and cellular users could affect the throughput performance of D2D pairs.

In [30], a resource allocation strategy based on Soft Frequency Reuse (SFR) was proposed, taking into account both licensed and unlicensed bands for D2D communications and using power control to prevent interference. The simulation results showed that the suggested strategy outperformed the traditional allocation scheme, which used only the licensed band and did not support D2D in terms of system capacity and blockage rate. In [31], a strategy was proposed to control transmission power, considering only a single CUE that was sharing resources with multiple D2D pairs. The assumptions of this study relied on predetermined values such as the constant distance between the D2D transmitter and receiver, constant transmission power, and constant SINR thresholds. The derivation of the analytical model was simplified by these deterministic assumptions, which may often be unrealistic.

This study aimed to:

- Propose a dynamic transmission power strategy for D2D transmitters. The proposed strategy aimed to control the transmission power for D2D transmitters under interference and capacity improvement constraints, enable D2D communication to mitigate interference, and run in polynomial time.
- Evaluate the proposed transmission power control strategy based on a 5G environment model, simulating a real-time environment for 5G networks.
- Carry out a MATLAB simulation to evaluate the performance of the proposed transmission power control strategy, use different performance metrics to investigate its feasibility, consider the average and the gained average throughput of the system, and measure the range of the transmission power value of the D2D transmitters.

III. SYSTEM MODEL

This study considered a single Macrocell scenario, where the Macrocell BS was located in the cell's center. Set D represents all D2D pairs in the system where D = [1, 2, 3,..., n]. The D2D pairs were randomly distributed within Macrocell coverage. In addition, the in-band spectrum strategy was assumed, considering an underlay mode, where D2D communication and CUE used the same licensed spectrum. Accordingly, D2D communication would reuse the resources of CUE. Thus, the problem of interference would increase. This study considered cross-tier interference. There are two scenarios of interference in this context. Figure 1 shows the scenario of the downlink transmission mode, where the CUE experiences interference from the D2D transmitters. Figure 2 shows the scenario of the uplink transmission mode, where D2D transmitters produce interference on the Macrocell BS.

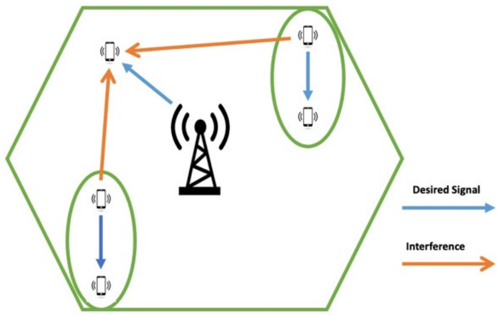

Fig. 1. Downlink scenario.

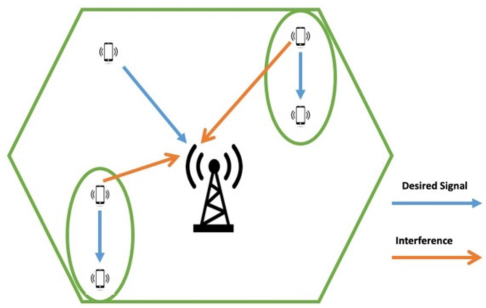

Fig. 2. Uplink scenario.

First, the downlink transmission mode is discussed. Assuming P_{Tx} is the transmitted power of the Macrocell BS, the received power P_{Rx} by CUE in terms of the downlink is modeled as follows:

$$P_{Rx} + P_{Tx} \ . \ G_M + \sum_1^n P_D \ . \ G_D \quad (1)$$

where G_M denotes the channel gain between the Macrocell BS and its attached CUE, given as follows:

$$G_M = PL_M \ . \ \lambda_M \quad (2)$$

G_D denotes the channel gain between CUE and its interfered D2D transmitter, given as follows:

$$G_M = PL_D \ . \ \lambda_D \quad (3)$$

where PL_M represents the path loss between the Macrocell BS and its CUE. PL_D represents the path loss between the D2D transmitter and CUE, λ_M represents the small-scale fading of the Macrocell BS channel and its CUE, and λ_D represents the small-scale fading of the D2D pair channel to the cellular UE.

The calculation of the distance between the transmitter and the receiver nodes influences the calculation of the path loss. The distance between the transmitter and receiver nodes causes a propagation loss. Thus, the distance between the transmitter and receiver is given according to the following formula [32]:

$$\delta_i = \sqrt{r_M^2 + r_D^2 - 2\, r_M\, r_D \cos\theta_i} \quad (4)$$

where r represents the radius, and θ_i is randomly distributed in [0, 2π]. In the downlink transmission mode, the received signal by the CUE is given as follows [33]:

$$S = \lambda_M \sqrt{P_M\, \delta_M^{-\alpha}\, h_M} + \lambda_D \sqrt{P_D\, \delta_D^{-\alpha}\, h_D} \quad (5)$$

where h_M represents the signal transmitted from the Macrocell BS, h_D represents the signal transmitted from the D2D transmitter, $P_M\, \delta_M^{-\alpha}$ denotes the received power from the Macrocell BS, $P_D\, \delta_D^{-\alpha}$ denotes the received interfering signal from the D2D transmitter, and a is the path loss coefficient. Path loss is given as follows [34]:

$$PL_{M_{dB}} = 128.1 + 37.6 \log d \,[\text{Km}] \quad (6)$$

where d is the distance in Km. Equation 6 is used when CUE is linked to the Macrocell BS, CUE is linked to the D2D, and D2D is linked to the Macrocell BS. However, the path loss for D2D communication is given as follows:

$$PL_{D_{dB}} = 148 + 40 \log d \,[Km] \quad (7)$$

In terms of downlink, the SINR at CUE can be modeled according to the following:

$$\psi_{DL} = \frac{P_M \cdot G_{M,CUE}}{\sum_1^n \varepsilon\, P_D \cdot G_{D,CUE} + N_0} \quad (8)$$

where ε has a value of 1 when the D2D pair and the CUE use the same subcarrier and 0 when this condition is not met. System noise is represented by N_0. In terms of uplink transmission mode, the SINR at Macrocell BS can be formulated as follows:

$$\psi_{UL} = \frac{P_{CUE} \cdot G_{CUE,M}}{\sum_1^n \varepsilon\, P_D \cdot G_{D,M} + N_0} \quad (9)$$

where P_{CUE} represents the transmit power of CUE, P_D represents the interfering signal transmitted by the D2D transmitter, $G_{CUE,M}$ represents the channel gain between the CUE and Macrocell BS, and $G_{D,M}$ represents the channel gain between the D2D and Macrocell BS.

IV. THE PROPOSED POWER CONTROL STRATEGY

An adequate transmission power control strategy could play an essential role in mitigating the impact of interference between network elements and improving the performance of the network. In this study, a transmission power control strategy was developed to alleviate interference between the Macrocell BS and D2D pairs and increase the capacity of the whole network. The main idea behind the proposed transmission power control strategy was to assist the D2D transmitter in adjusting its transmission power autonomously. The proposed transmission power control strategy allows D2D pairs to communicate with each other, addressing the interference challenge. The D2D transmitter reduces its transmission power when it interferes with adjacent CUEs and D2D pairs.

The Macrocell BS transmission power is assumed to be an essential parameter for the proposed transmission power control strategy. In addition, the coverage of the Macrocell where the D2D pairs are located is considered by the proposed transmission power control strategy. Consequently, the proportion between the Macrocell BS transmission power and its coverage is identified to derive a suitable transmission power level for the D2D transmitter. Thus, a proportional degree between the Macrocell BS transmission power and its radius should be recognized. The following formula was used to configure the proportional degree between Macrocell BS transmission power and its radius:

$$\delta = \frac{P_{Tx}}{\chi_m} \quad (10)$$

where P_{Tx} is the Macrocell BS transmission power, and χ_m is calculated as follows:

$$\chi_m = \log_{10}(R_m) \quad (11)$$

where R_m is the Macrocell radius. Accordingly, the D2D transmitter established its transmission power based on the following formula:

$$P_{D_t} = maximum(\delta \,.\, \chi_D \;,\; P_{D_{MAX}}) \quad (12)$$

$P_{D_{MAX}}$ was set to 20 dBm and χ_D was calculated as follows:

$$\chi_D = \log_{10}(R_D) \quad (13)$$

where R_D represents the distance between the D2D transmitter and the D2D receiver.

The D2D transmitter should determine the number of victim elements that interfered with its transmitted signals. In this case, the coverage of the D2D transmitter is considered to have a number of victims that are affected. The coverage depends on the distance between the D2D transmitter and the D2D receiver. The following formula was used to specify the area where other network elements could be affected and interfered with:

$$A = \pi\,(2 \,.\, R_D) \quad (14)$$

where A represents the threshold of the possible distance in which network elements could interfere with and be affected by the D2D transmitter signal. After the number of victims is recognized, the D2D transmitter can derive a cost function to reduce its transmission power based on the impact of the interference on adjacent victims. The cost function was calculated for each active D2D pair according to:

$$\psi_i = \frac{\Omega_i}{\tau} \quad (15)$$

where τ represents the total active elements of the system such as the D2D transmitter and CUE, and Ω_i represents the number of elements that interfered with a D2D transmitter. Table I is used to construct Ω_i for every active element in the system.

TABLE I. CONSTRUCTED COST FUNCTION

	E_1	E_2	E_3	…	E_n
E_1	0	1	0	…	1
E_2	1	0	1	…	1
E_3	0	1	0	…	0
E_4	1	1	0	…	
…	…	…	…	…	…
E_n	1	1	0	…	0
Ω_i	Ω_1=3	Ω_2=4	Ω_3=1	…	Ω_n=2

Accordingly, the proper level of transmission power for every D2D transmitter can be derived based on the following:

$$P_{D_{i\,(t+1)}} = P_{D_{i\,t}} - \left[P_{D_{i\,t}} \,.\, \psi_i\right] \tag{16}$$

The pseudo-code of the proposed transmission power control strategy is presented below.

```
Inputs ← P_Tx, R_m, D
Get:χ_m, δ
while D ≤ 1 do
    For i = 1 to D do
        Compute: P_{D_it} = λ. χ_iD
    End For
    For i = 1 to D do
         Compute A_i
         Compute: ψ_i = Ω_i/τ
         Compute: P_{D_i(t+1)} = P_{D_it} − [P_{D_it} . ψ_i]
   End For
End While
END
```

V. RESULTS

A simulation was carried out to evaluate the proposed transmission power control strategy in a single Macrocell scenario, with the Macrocell BS located in the cell's center. D2D pairs and CUEs were randomly located within the Macrocell extent. As D2D pairs would increase network capacity and interference, the distance between the D2D transmitter and the receiver should not be long. In this context, the maximum distance between the D2D transmitter and receiver was set at 40 m. D2D communication was used to offload traffic from the Macrocell BS, using the model mentioned above. Channel conditions such as noise and path loss were simulated, and Table II summarizes the assumptions and simulation parameters. The antenna type was omnidirectional, the white noise spectral density was -174 dBm/Hz, and the channel bandwidth was 15 MHz. Interference occurs when the D2D pairs communicate because the spectrum resources are reused. Therefore, a power control/management strategy was used to alleviate the impact of undesirable interference. According to 3GPP standards, UEs are classified into four classes based on their frequency band, and there is a minimum and maximum level of transmit power for each class. This study considered class 3 for UEs, which represent D2D transmitters. The minimum transmission power was set at 23 dBm for class 3 UEs for all frequency bands, and this class is an obvious example of handheld UEs [35]. The maximum distance between the D2D elements was set to 40 m, to ensure that the D2D transmitters are connected to the closest receivers to mitigate interference and avoid excessive power.

TABLE II. SIMULATION PARAMETERS

Parameters	Value
Maximum distance between D2D elements	40 m
Maximum D2D Tx power - $P_{D_{MAX}}$	23 dBm
Fixed D2D Tx power - P_D	23 dBm
Macrocell Tx power - P_{TX}	46 dBm
Frequency band	1900 MHz
Channel bandwidth	15 MHz
Antenna mode	Omni-Directional
Maximum number of D2D pairs	25 Pairs
N_0	-174 dBm/Hz

Three power control methods were used in the simulation; the proposed transmission power control strategy, the fixed-based approach with fixed transmission power at 20 dBm without changes, and the range-based approach using (12). The third approach adjusts the transmission power of the D2D transmitter based on its distance from the receiver. The fixed-based approach was considered because it is used in real implementations where the D2D transmitter uses the maximum predefined transmission power. The range-based approach adjusts the transmission power according to the distance acknowledged between the transmitter and the receiver to alleviate interference by decreasing the transmission power when the distance is short.

Figure 3 shows the network average throughput, presenting the total capacity of the network, including Macrocell and the active D2D pairs. The number of D2D pairs increased in each run to analyze the simulated power control strategies. The network capacity increased with the number of D2D pairs because traffic was offloaded to D2D pairs. The fixed transmission power strategy provided the best average throughput when the number of D2D pairs was low. In this case, the capacity was high because the D2D transmitter operates with the highest possible transmission power. Transmission power affects the quality of the transmitted signal, which in turn affects the data rate. However, the performance of the fixed transmission strategy decreased when the number of D2D pairs increased to more than 10. The average throughput of the fixed transmission power approach with 5 D2D pairs was better than with 10 or 15 D2D pairs since the interference in the first case was less. The figure shows that the average throughput of the fixed transmission power approach constantly increased when the number of D2D pairs became more than 15. The range-based strategy provided the worst average throughput, as its behavior did not change with the number of D2D pairs. The range-based power control strategy tended to control the transmission power of the D2D transmitter according to the calculated distance from the receiver. As a result, the short distance between them leads to low transmission power and low data rates. On the other hand, the proposed transmission power control strategy could control transmission power considering interference and network capacity, providing acceptable average throughput for less than 10 D2D pairs. In this case, the proposed strategy delivered lower average throughput than the fixed transmission power approach, but higher than the range-based approach. However, for more than 10 D2D pairs, the proposed transmission power control strategy provided the best average throughput, as it increased by nearly 11% and 35% compared to the fixed and range-based approaches, respectively. The proposed transmission power control strategy constantly increased the average network throughput four times when the number of D2D pairs increased from 1 to 25.

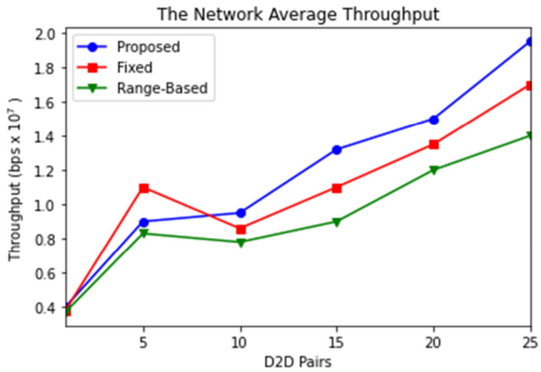

Fig. 3. The network average throughput.

Figure 5 shows the average throughput achieved by implementing D2D communication. Average throughput decreased as the number of D2D pairs increased due to the undesirable interference caused by them. In this case, a power control strategy is needed to mitigate interference and preserve the average gained throughput after implementing D2D communication. The range-based strategy delivered the worst average throughput, as its average throughput constantly decreased when the number of D2D pairs increased. According to the figure, the average throughput delivered by the range-based strategy decreased by nearly 73% when the number of D2D pairs increased from 1 to 25. The fixed transmission power approach delivered the best average throughput when the number of D2D pairs was less than 10. However, when the number of D2D pairs increased to more than 10, its average throughput decreased. The fixed transmission power approach performed well for less than 10 D2D pairs, but this does not support a real environment where the number of D2D pairs would exceed this number. The fixed transmission power approach performs better with fewer D2D pairs because the distance between different distributed D2D pairs is long. As a result, the impact of interference on distributed D2D pairs is not robust. However, when the number of D2D pairs increases, the impact of interference becomes robust. The average throughput of the fixed transmission power approach decreased by nearly 65% when the number of D2D pairs increased from 1 to 25. On the other hand, the proposed transmission power control strategy delivered the best average throughput for more than 10 D2D pairs. The proposed transmission power control strategy performed the best, preserving the gained capacity, as it managed the transmission power considering both the interference and throughput aspects. Mitigating interference leads to increased capacity. Thus, the average throughput degradation of the proposed strategy is the least compared to the others. The average throughput of the proposed transmission power control strategy decreased by nearly 58% when the number of D2D pairs increased from 1 to 25. According to Figure 4, the proposed transmission power control strategy performed better when the number of D2D pairs increased, which simulates a real environment, while the fixed transmission power approach performed better for less than 10 D2D pairs.

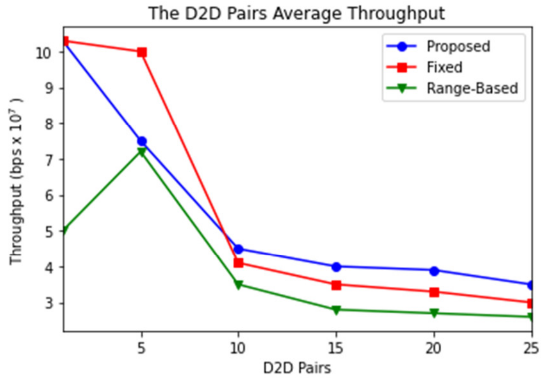

Fig. 4. D2D pairs average throughput.

Figure 6 shows the average transmission power for the D2D transmitters. As the transmission power of the fixed transmission power approach was set to 20 dBm, there were no changes when the number of D2D pairs changed. However, the proposed transmission power control strategy enables D2D transmitters to change their transmission power to mitigate interference, especially when the number of D2D pairs increases. Consequently, the average transmission power ranged between 12 and 16 dBm. In addition, the average transmission power level constantly decreased as the number of D2D pairs increased. The average transmission power of the proposed strategy did not reach maximum, while it provided the best throughput compared to the other strategies. The average transmission power level of the range-based strategy was the lowest, as it ranged between 3.5 and 7 dBm, but delivered the worst performance in terms of average throughput compared to the other approaches. The proposed transmission power control strategy had 15% and 30% better network capacity compared to the fixed-based and range-based approaches, respectively. The average throughput of the D2D pairs for the proposed transmission power control strategy was 16.6% and 35% better than the fixed-based and range-based approaches, respectively.

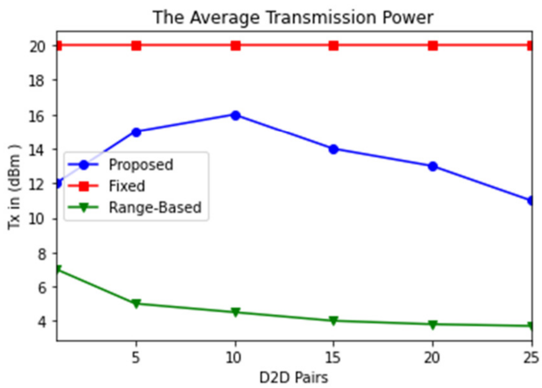

Fig. 5. Average transmission power for D2D transmitters.

When the number of D2D pairs increases beyond 25, two scenarios will happen according to the simulation results. At first, the throughput of the entire network would increase as traffic is offloaded from the main cell to D2D pairs. However, the level of additional capacity gained for the entire network would remain stable as D2D pairs are added due to interference. In the second scenario, the throughput of the D2D pairs communication would decrease when the number of D2D pairs increases due to interference and its undesirable impact on throughput.

VI. CONCLUSION

D2D communication has been recognized as one of the most promising developments in 5G networks, as it allows nearby devices to be directly connected without going through the main base station, improving network capacity. However, managing the interference introduced by the D2D transmitter and maximizing the efficiency of the UE power consumption have become essential requirements for implementing D2D communications. This study proposed a dynamic transmission power control strategy for D2D transmitters to allow them to dynamically adjust their transmission power, alleviate interference, and improve network capacity. The main factors considered in the proposed strategy were the number and distance of the D2D pairs that are affected by interference. A simulation was carried out to validate the proposed transmission power control strategy, and the results demonstrated its effectiveness compared to the fixed and range-based approaches.

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