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Inter-clustering Cooperative Relay Selection Schemes for 5G Device-to-device Communication Networks

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Abstract

The ongoing adoption of 5G will increase the data traffic, throughput, multimedia services, and power consumption for future wireless applications and services, including sensor and mobile networks. Multipath fading on wireless channels also reduces the system performance and increases energy consumption. To address these issues, device-to-device (D2D) and cooperative communications have been proposed. In this study, we propose two inter-clustering models using the relay selection method to improve system performance and increase energy efficiency in cooperative D2D networks. We develop two inter-clustering models and present their respective algorithms. Subsequently, we run a computer simulation to evaluate each model's outage probability (OP) performance, throughput, and energy efficiency. The simulation results show that inter-clustering model II has the lowest OP, highest throughput, and highest energy efficiency compared with inter-clustering model I and the conventional inter-clustering-based multirelay method. These results demonstrate that inter-clustering model II is well-suited for use in 5G overlay D2D and cellular communications.

Index Terms: Device-to-device communication, Energy efficiency, Inter-clustering, Relay selection

I. INTRODUCTION

Cellular communication systems are the world's most widely used mode of communication. Although already on an expanding trajectory, cellular communication systems received a further boost by the introduction of 5G [1,2]. One future consequence of the ongoing 5G adoption will be a significant bump in the number of active devices. Furthermore, an increase in the number of resources, such as base stations (BSs), to facilitate 5G adoption will increase data traffic, consumption of multimedia services, and throughput. All this will lead to significant increase in energy consumption [3]. Meanwhile, the growing popularity of mobile communication devices has given rise to a phenomenon of multidevice sharing of interactive multimedia services in one particular location [4], which can increase the energy consumption of mobile devices [3]. Consequently, the battery power of the user's device runs out quickly and needs to be recharged frequently. One of the objectives of 5G communication systems is to achieve energy efficiency. Furthermore, if the energy consumption in mobile communication is not promptly reduced, a negative environmental impact cannot be avoided [5].

The 5G technology comes with another major issue: multipath fading, which impairs network performance and increases energy usage [6]. Multipath fading is a major problem in a wireless channel that occurs when a signal is sent through multiple paths from the transmitter to the receiver. The signal undergoes changes during its propagation, resulting in different received signal strengths by the receiver. To fix this

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issue, device-to-device (D2D) communication and cooperative communication have been developed. Furthermore, the adoption of D2D technology, which allows peer-to-peer (P2P) communication between devices to lower the BS traffic load in one cell, in combination with long-range (LR) and short-range (SR) communication, is one solution to the energy efficiency challenges in mobile communication. In recent times, D2D communication has become a widely researched topic in the domain of long-term evolution-advance (LTE-A) development. D2D communication allows P2P communication between devices within the cellular frequency range to lower the BS load in a single cell. Therefore, D2D communication enables SR communication without straining the BS. Moreover, this communication scheme can accommodate services, such as multimedia services, that need large amounts of data.

In D2D communication, two user devices communicate directly without passing through a BS [7]. In-band and out-band D2Ds are two spectrum types of D2D communication. The key goal of D2D communication is to increase coverage, reduce traffic load, boost spectrum consumption and network capacity, provide ultra-low latency and high bit rates, and improve service quality [8,9]. Because D2D communication occurs between devices that are close to each other, it can meet the requirements of high data rate, network capacity, and energy efficiency. D2D communication can provide such services as content-sharing, multiplayer gaming, and proximity-aware social networking [10].

Cooperative communication systems, meanwhile, use the nature of wireless channels with diversity gained through the relaying method, where a source can send signals to several nearby devices, as relays, to be forwarded to the destination. The receiver can receive multiple replicas of the information signal sent by the source via one or more relays. Replica signals sent from multiple paths simultaneously to the receiver can reduce the effect of multipath fading, thus improving system performance. Similar to D2D communication, cooperative communication also bypasses the need for a BS, thus achieving a more efficient use of resources.

To enhance the energy efficiency and preserve the quality of 5G wireless technology networks, the merging of cooperative systems with D2D is required. Therefore, as the communication technology enters the 5G era, the integration of cooperative communication systems with D2D communication is being widely researched [11]. Cooperative communication systems can select the best relay with good performance and low energy consumption [12,13]. Furthermore, compared with traditional systems, D2D consumes lesser energy. In this study, we propose a clustering-based D2D cooperative communication system to improve system performance and energy efficiency.

Several studies have introduced the concept of D2D clustering, which allows adjacent wireless devices to share shared resources to reduce system bandwidth and energy resources [14]. The D2D clustering incorporates social interactions and physical relationships among terminal users. However, it was not considered the cooperative mechanism in the communication system. Another study focused on clustering in D2D systems to improve throughput [15]. However, it explored only the distribution of nodes in a cluster without using a cooperative mechanism. In addition, a previous study on D2D clustering based on channel design was conducted to improve the user experience in terms of throughput and energy efficiency in 5G networks [16]. Other studies, meanwhile, focused on integrating clustering modes in D2D systems to boost performance, reduce latency, and save energy [17]. However, 5G technology is predicted to improve the performance of wireless network-based infrastructure for a broader range of applications, including Internet of Things (IoT), sensor networks, mobile networks, and vehicular ad hoc networks (VANETs) [18,19]. The D2D cooperative system is one of the best options for meeting these service needs as cooperative D2D allows high throughput, high energy efficiency, broad coverage, and low cost for mobile-to-mobile, sensor-to-sensor, or car-to-car communication [20]. Therefore, this study proposes a D2D cooperative clustering model that uses a relay selection technique to examine the outage probability (OP), throughput, and energy efficiency.

This study offers two inter-clustering cooperative D2D models that use the relay selection method in a cluster to reduce the BS overload and network energy consumption [21]. As D2D cannot completely replace cellular communication and still needs to share data with the BS, the suggested paradigm is a hybrid model that allows D2D and cellular communication to work together. Inter-clustering model I determines which cluster head (CH) is closest to the BS, while the source selects the best relay to deliver information to the CH, which is transferred to another cluster's CH via the BS. In inter-clustering model II, the source selects the optimal relay to serve as the CH of a cluster, forwarding information to another cluster's CH through the BS. This study then uses computer modeling to evaluate the OP performance, throughput, and energy efficiency of each model. Finally, the performance simulation results of the proposed models are compared with a conventional clustering model based on multirelay cooperatives. The following is a summary of the contributions of this study.

a. We propose two D2D cooperative inter-clustering models using the relay selection method.
b. We provide mathematical analysis for the OP, throughput, and energy efficiency of each proposed D2D cooperative inter-clustering model.

II. SYSTEM MODEL

The D2D cooperative clustering system model is considered in a single-cell environment to increase throughput, where each user communicates in dual modes, specifically, D2D and cellular [22]. The proposed D2D inter-clustering network model involves multiple user devices that form a cluster that sends data to the target cluster. D2D cooperative clustering is a network in which a source in a cluster broadcasts information that is then sent to multiple adjacent devices to work together to relay the information to additional relay nodes. As each cluster uses a proactive relay selection approach to maintain its performance and save energy during clustering [23], D2D cooperative clustering is a more efficient method than the reactive relay selection method. This study focuses on two inter-clustering information transmission network models.

A. Inter-Clustering Model I

Inter-clustering model I is a D2D cooperative clustering method that uses a proactive relay selection method in a cellular communication network, as illustrated in Fig. 1. The source of each cluster sends training bits in parallel to many relays to create a multirelay network. At this point, one of the relays is selected as the best relay using the max-min criterion [24]. This information is then sent from the source to the best relay and forwarded to the cluster head. It is assumed that the cluster head closest to the BS is known. The cluster head then sends the information to the BS and forwards it to another cluster head as the destination. After selecting the best relay, the transmission of this information corresponds to the concept of a D2D multihop. Therefore, inter-clustering model I adopts the idea of multirelay and multihop D2D networks in cooperative communication systems.

Technically, the process of sending information in inter-clustering model I progresses in the following steps:

1. The source sends the training bit (x_t) broadcast to several nearby relays (l) in the form of a multirelay in a cluster to estimate the SNR value of each relay and determine the best relay. The signal received by each relay can be expressed as

$$\hat{y}_{t_i} = x_t h_{t_i} + n_{t_i}, \tag{1}$$

where $\hat{y}_{t_i}$ is the training bit signal received on relay i, h_{t_i} is the fading coefficient on link relay i, and n_{t_i} is Additive white Gaussian noise (AWGN) on link relay i, i=(1, 2, ..., l).

2. Each relay i sends feedback to the source using the SNR value between the source and relay i as the input data to identify the best relay. The SNR of each relay was calculated as follows [25]:

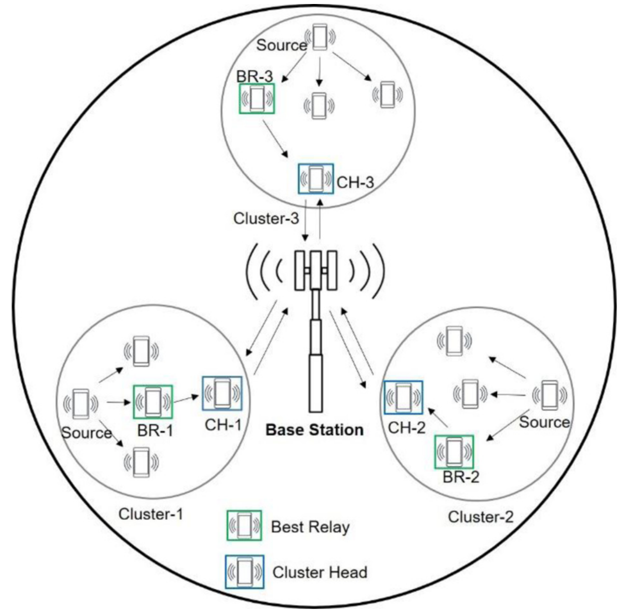

Fig. 1. The proposed inter-clustering cooperative D2D model I.

$$SNR_{R_i} = \frac{P_{R_i} |h_{t_i}|^2}{N_{t_i}}, \tag{2}$$

where P_{R_i} is the power of relay i and N_{t_i} is the noise power of relay i.

3. Based on the estimated value of SNR_{R_i}, the best relay R_b, can be determined using the max-min theory approach [24], as follows:

$$R_b = \arg\max\min\ \{SNR_{R_i}\}. \tag{3}$$

4. The source sends an information signal (x_s) to the best relay, and the signal received by the relay can be expressed as

$$y_{R_b} = x_s h_{R_b} + n_{R_b}, \tag{4}$$

where h_{R_b} is the fading coefficient of the best relay link and n_{R_b} is the AWGN on the best relay link.

5. In this study, the relay used was the amplify-andforward (AF) protocol, and the signal received by the relay was amplified as follows [26]:

$$\beta_{R_b} = \sqrt{\frac{P_{R_b}}{|h_{R_b}|^2 P_S + N_0}}, \tag{5}$$

where P_{R_b} is the power of the best relay, P_S is the power of the source, and N_0 is the noise variance in the channel.

6. The best relay sends data to CH j, and the received signal can be written as

$$y_{CH_j} = \beta_{R_b} x_s h_{CH_j} + n_{CH_j}, \tag{6}$$

where h_{CH_j} is the fading channel coefficient of CH link j, and n_{CH_j} is the AWGN on CH link j, j=1, 2, ..., k.

7. Cluster head j sends information to the BS as a relay, and the received signal can be expressed as follows:

$$y_{BS} = y_{CH_j} h_{BS} + n_{BS}, \tag{7}$$

where h_{BS} is the fading channel coefficient of the BS link and n_{BS} is the AWGN on the BS link.

8. The BS passes information to the cluster head on another cluster as a destination, and is expressed as follows:

$$y_D = y_{BS} h_D + n_D, \tag{8}$$

where h_D is the fading channel coefficient of the destination link (another cluster) and n_D is the AWGN on the destination link (another cluster).

The computer simulation for inter-clustering model I was conducted using MATLAB. Based on the aforementioned steps, inter-clustering model I can be stated in the form of the following algorithm:

Algorithm Inter-clustering D2D Model I

```
begin
init relay i, x_t, ŷ_{t_i}, SNR_{R_i}, R_b, x_S, y_{R_b}, β_{R_b}, y_{CH_j}, cluster head j,
y_{BS}, bs, y_D, d
while source send x_t to i relay
    define ŷ_{t_i}
    for i = 1 to l do
        calculate SNR_{R_i}
    end for

    select the best relay R_b
    while x_S send to R_b
        define y_{R_b}, β_{R_b}, y_{CH_j}
        send y_{CH_j} to cluster head j
        for cluster head j = 1 to k do
            define y_{BS}
            send y_{BS} to BS
        end for
        define y_D
        forward y_D to D
    end while
end while
end
```

B. Inter-clustering Model II

Inter-clustering model II uses a cellular network similar to model I. However, the relay selection process determines the best relay for the cluster head. In other words, multiple users form a cluster and the source chooses the best relay criteria for selecting the cluster head. Furthermore, as shown in Fig. 2, inter-clustering model II consists of multiple clusters in a cellular network. A cluster contains a large number of users acting as sources and multiple relays selected as cluster heads using the proactive relay-selection technique. After the cluster head selection process, the source provides the cluster head with information that is sent to the BS and cluster head destinations of other clusters. Therefore, inter-clustering model II requires fewer processes to transfer information from one cluster to the target cluster.

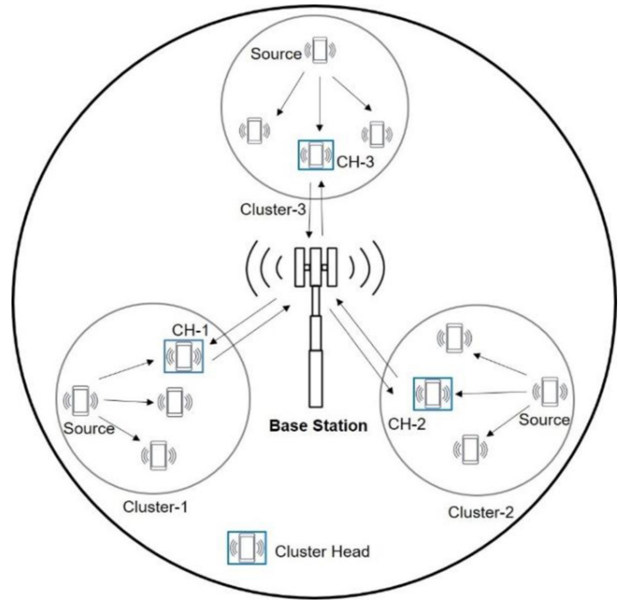

Fig. 2. The proposed inter-clustering cooperative D2D model II

Inter-clustering model II progresses in the following steps:

1. The first and second steps are the same as in model I; namely, the source sends training bits (x_t) broadcast to several nearby relays (l) in the form of multiple relays in a cluster to determine the SNR value of each relay, which is used to determine the cluster head. The signal received by each relay is the same as that in Eq. (1).
2. Relay (i) sends feedback to the source using the SNR value between sources and relay i as input data to determine the cluster head. The SNR of each relay can be calculated using Eq. (2).
3. Based on the estimated value of SNR_{R_i}, the cluster head R_{CH_i} can be determined using the max-min theory [24] as follows:

$$R_{CH_i} = \arg\max\min \ \{SNR_{R_i}\}. \tag{9}$$

4. The source sends information (x_s) to the selected relay as the CH, and the received signal on the CH is amplified by the amplification factor of the AF protocol and can be expressed as follows:

$$y_{CH} = \beta_{CH} x_s h_{CH} + n_{CH}, \tag{10}$$

where h_{CH} is the fading channel coefficient of the CH link, n_{CH} is the AWGN on the CH, and β_{CH} is the amplification factor of the AF protocol process, which can be expressed as:

$$\beta_{CH} = \sqrt{\frac{P_{CH}}{|h_{CH}|^2 P_S + N_0}}, \quad (11)$$

where P_{CH} is the power of the CH.

5. The cluster head then forwards the information to the BS, which can be expressed as in Eq. (7).
6. Next, the BS transmits information to other cluster head destinations, which can be expressed as in Eq. (8).

Inter-clustering model II was simulated using MATLAB programming, and based on the aforementioned steps, inter-clustering model II can be stated in the form of the following algorithm:

Algorithm Inter-clustering D2D Model II

```
begin
init relay i, x_t, ŷ_ti, SNR_Ri, R_b, x_S, y_Rb, β_Rb, y_CHj, cluster head j, y_BS,
bs, y_D, d
while source send x_t to i relay
      define ŷ_ti
      for i = 1 to l do
            calculate SNR_Ri
      end for
      select the best relay R_b
      while x_S send to R_b
            define y_Rb, β_Rb, y_CHj
            send y_CHj to cluster head j
            for cluster head j = 1 to k do
                  define y_BS
                  send y_BS to BS
         end for
         define y_D
         forward y_D to D
   end while
end while
end
```

III. OUTAGE PROBABILITY, THROUGHPUT AND ENERGY EFFICIENCY

A. Outage Probability

OP indicates the overall service quality of the system and is an important parameter in wireless communication networks. The probability that the SNR value at the destination falls below a preset threshold value was used to calculate the OP. OP (P_{out}) can be expressed as follows [27]:

$$P_{out} = Pr\{\gamma < \gamma_{th}\} = Pr\{min(\gamma_{CH_i}, \gamma_D) < \gamma_{th}\}, \quad (12)$$

where γ is the SNR of the system, and γ_{th}, γ_{CH}, γ_D are the SNR threshold of the system, SNR of the CH, and SNR at the destination, respectively.

B. Throughput

Throughput, another important performance factors of communication systems, is calculated based on the amount of data transferred over a specified distance and time (bits per second (bps)). The higher the achievable throughput, the higher the transmission-link quality, and vice versa.

In both models, the throughput (Th) is calculated based on the OP and data rate values (R_B), and can be represented as follows:

$$Th = (1 - P_{out}) \times R_B, \quad (13)$$

where R_B is the bit rate from source to destination in bits/s.

C. Energy Efficiency

To obtain the energy efficiency of each proposed model, we first calculated the energy consumption of each model. Next, we compared the energy consumption of each model with the conventional energy consumption, that is, a model that does not use relay selection. For example, the energy consumption of inter-clustering model I is as follows:

$$E_{C1} = \frac{\Sigma_{i=1}^{k} P_{S,R_i} + \Sigma_{i=1}^{k} P_{R_i,CH_i} + \Sigma_{i=1}^{k} P_{CH_i,T_i} + P_{BS,D}}{R_B}, \quad (14)$$

where $P_{S,Ri}$ is the power consumption in W units for transmitting data bits from the source to the i-th relay, which can be written as

$$P_{S,R_i} = \frac{P_S |h_{S,R_i}|^2}{d_{S,R_i}^{\alpha} N}, \quad (15)$$

where P_S is the transmission power or the power required to transmit information from the source, $h_{S,Ri}$ is the effect of fading between the source and the i-th relay, $d_{S,Ri}$ is the distance between the source and the i-th relay, α is the exponential path loss, and N is the AWGN.

The power consumption for sending data bits from the i-th relay to the CH can be expressed as follows:

$$P_{R_i,CH_i} = \frac{P_{R_i} |h_{R_i,CH_i}|^2}{d_{R_i,CH_i}^{\alpha} N}, \quad (16)$$

where P_{R_i} is the transmission power or power required to transmit information from i-th relay, d_{R_i,CH_i} is the distance between the i-th relay and the CH, and h_{R_i,CH_i} are the effects of fading between the i-th relay and the CH.

The power consumption for sending data bits from the CH to the BS is

$$P_{CH_i,BS} = \frac{P_{R_i}|h_{CH_i,BS}|^2}{d^{\alpha}_{CH_i,BS}N}, \quad (17)$$

where $h_{CH_i,BS}$ is the effect of fading between the cluster head and BS, and $d_{CH_i,BS}$ are the distances between the CH and BS. Subsequently, the power consumption for transmitting data bits from the BS to the destination is expressed as follows:

$$P_{BS,D} = \frac{P_{BS}|h_{BS,D}|^2}{d^{\alpha}_{BS,D}N}, \quad (18)$$

where P_{BS} is the transmission power or power required to transmit information from the BS, $d_{BS,D}$ is the distance between the BS and destination, and $h_{BS,D}$ is the effect of fading between the BS and destination.

The following equation is used to calculate the total energy consumption in inter-clustering model II:

$$E_{C2} = \frac{\Sigma^k_{i=1}P_{S,CH_i} + \Sigma^k_{i=1}P_{CH_i,BS} + P_{BS,D}}{R_B}, \quad (19)$$

where P_{S,CH_i} are the power consumptions for transmitting data bits from the source to the i-th CHs. The power from the source to the cluster is calculated as follows:

$$P_{S,CH_i} = \frac{P_S|h_{S,CH_i}|^2}{d^{\alpha}_{S,CH_i}N}, \quad (20)$$

where d_{S,CH_i} is the distance between the source and the i-th CHs, and h_{S,CH_i} are the effects of fading between the source and the i-th CHs.

The energy consumption for a system without relay selection (RS) or conventional multirelay clustering can be calculated as follows:

$$E_{Non\ RS} = \frac{\Sigma^k_{i=1}P_{S,R_i} + \Sigma^k_{i=1}P_{R_i,CH_i} + \Sigma^k_{i=1}P_{CH_i,BS} + P_{BS,D}}{R_B}, \quad (21)$$

where the definition of each variable has been defined in the previous equation.

Based on Eqs. (14), (19), and (21), the energy efficiency for each model can be written as

$$EE_1 = \frac{E_{Non\ RS} - E_{C1}}{E_{Non\ RS}} \times 100\%, \quad (22)$$

and

$$EE_2 = \frac{E_{Non\ RS} - E_{C2}}{E_{Non\ RS}} \times 100\%. \quad (23)$$

IV. RESULTS AND DISCUSSIONS

This section presents the simulation results for the two proposed D2D cooperative inter-clustering models using relay selection strategies in terms of the OP performance, throughput, and energy efficiency. A comparison of the two models with the traditional multirelay-based D2D clustering model is also presented. The simulation considers several parameters such as the LTE-A maximum data rate of 450 Mbps [28], maximum distance for D2D communication of 200 m [29], maximum transmit power of 0.5 W [12], exponential path loss of 2.5, and the 16-QAM modulation technique (which is a commonly used modulation type in 5G technology) [30].

A. Outage Probability

Based on the analysis in the previous section, simulations were performed to calculate the OP of each proposed model in both inter-clustering and conventional clustering models based on multiple relays. As shown in Fig. 3, the OP was first simulated against the transmit power. According to the D2D communication standard [12], the maximum transmit power is 0.5 W. Simulation results for the three models, compared to inter-clustering I and conventional clustering networks, show that the proposed inter-clustering II produces the lowest OP. Thus, inter-clustering II has better OP performance because it has a lower information transmission error rate, supported by good link channel conditions. In the inter-cluster II model, the source transmits information directly to the cluster head selected as the best relay, minimizing link transmission errors.

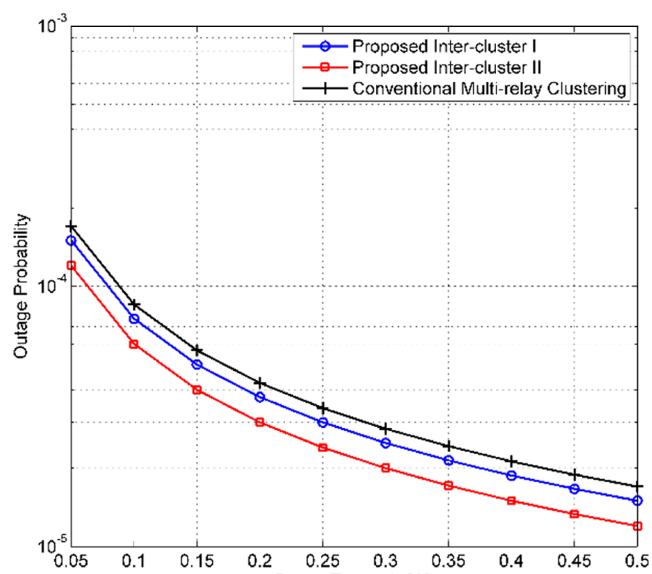

Fig. 3. Outage probability versus power transmit of clustering cooperative D2D.

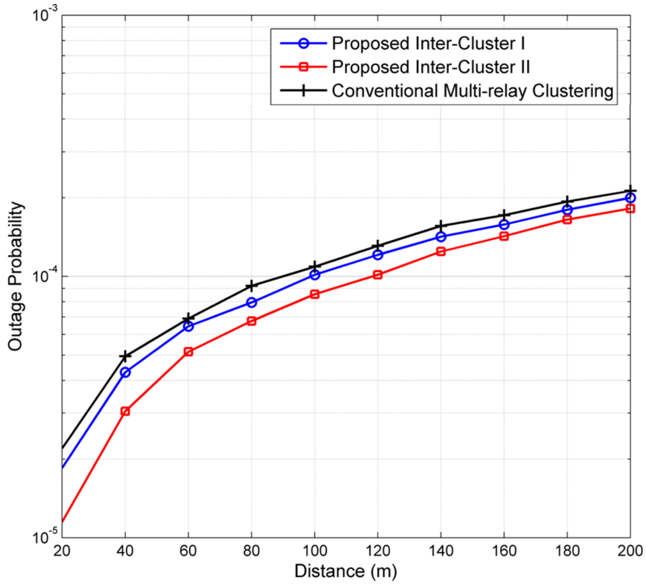

Fig. 4. Outage probability versus power transmit of clustering cooperative D2D.

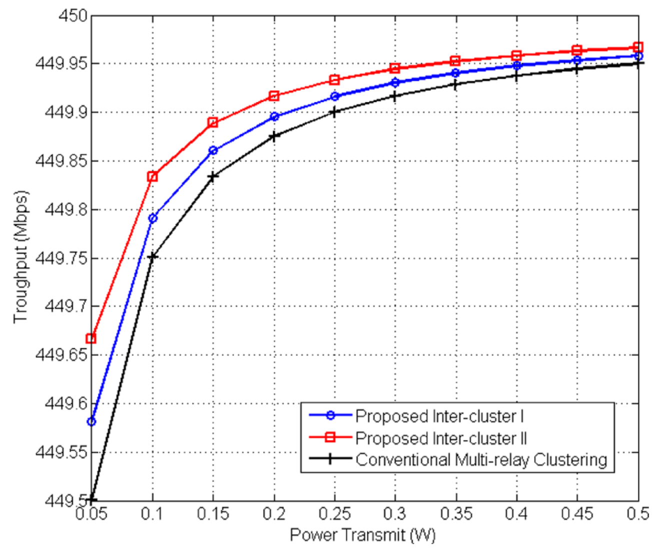

Fig. 5. Throughput versus power transmit of clustering cooperative D2D.

In short, the first model provides the source with many opportunities to choose the best cluster head with a high signal-to-noise ratio and improves the success rate of sending data to the destination. However, in the inter-clustering I model, the source delivers information to the best relay, which then forwards it to a predetermined cluster head, allowing channel conditions, particularly the resulting SNR value, to fall below the threshold, resulting in an outage condition. Similarly, in conventional systems, where the source sends information to numerous adjacent relays to be relayed to the cluster head, the chance of outage conditions is greater because the SNR value is not estimated beforehand, as in the inter-clustering model utilizing the relay selection technique. The OP obtained by the three clustering network models shows that the OP decreases as the transmission power increases. In contrast, the proposed inter-clustering II model has the smallest or best OP. For each conventional D2D clustering network, when the maximum transmit power is 0.5, as in the proposed models I and II, the outage probabilities are 1.7×10^{-5}, 1.5×10^{-5}, and 1.2×10^{-5}, respectively.

Then, given the transmission distance, an OP simulation was run, and the simulation results are presented in Fig. 4. According to [29], the maximum link distance for D2D is 200 m. The simulation findings reveal that as the distance between the D2D links increases, the probability of an outage increases. This is because the signal quality decreases as the distance increases or the SNR value decreases, resulting in an increase in link outage conditions. However, the proposed inter-clustering I and conventional systems have higher OP values than the proposed inter-clustering II system.

B. Throughput

Throughput is the data transfer speed over network transmission media, with a peak data rate of 450 Mbps for LTE-A mobile devices [28]. Computer simulations were conducted to determine the throughput for the three D2D clustering network models using Eq. (13), considering the transmission power and link distance. Figure 5 shows the throughput simulation results for the power transmission in each D2D clustering model. In general, the simulation results show that throughput increases as the signal power increases because the signal quality improves, and the transmission error rate and outage conditions are small. The proposed inter-clustering model I had a better throughput than the other two D2D clustering network models. With a transmit power of 0.25 W, the throughputs of the proposed inter-clustering models I and II and the standard network model are 449.92, 449.98, and 449.90 Mbps, respectively. Based on the results of this simulation, the proposed inter-clustering cooperative D2D model II provides the highest throughput compared with the proposed inter-clustering model I and conventional clustering networks. The proposed inter-clustering model II can achieve 99.86% of the maximum data rate of 450 Mbps in terms of throughput.

The results of throughput against distance were also simulated, as shown in Fig. 6. The simulation results show that as the channel condition worsens, the longer the link distance, the lower the throughput, and as a result, the higher the transmission error rate. The proposed D2D inter-clustering models I and II and the conventional models achieved data throughputs of 449.915, 449.93, and 449.905 Mbps, respectively, over a transmission link distance of 200 m.

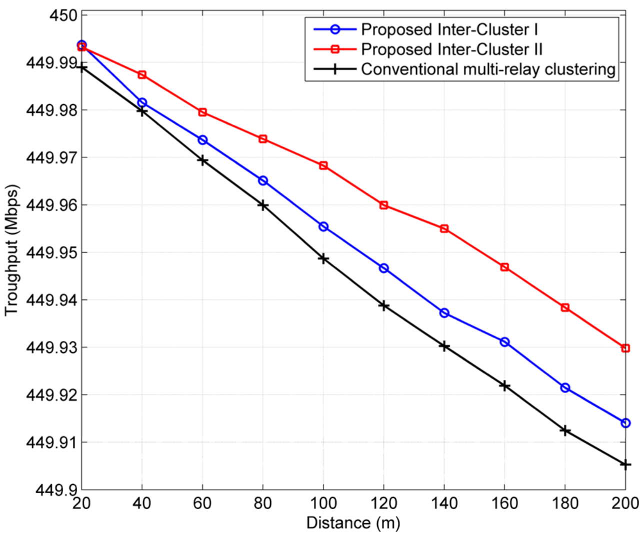

Fig. 6. Throughput versus distance of clustering cooperative D2D.

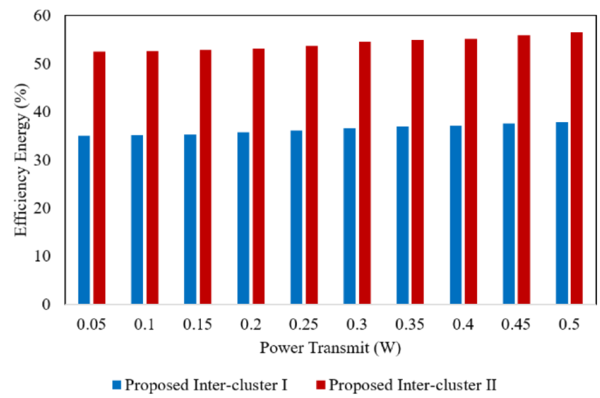

Fig. 7. Energy efficiency versus power transmit for clustering cooperative D2D models.

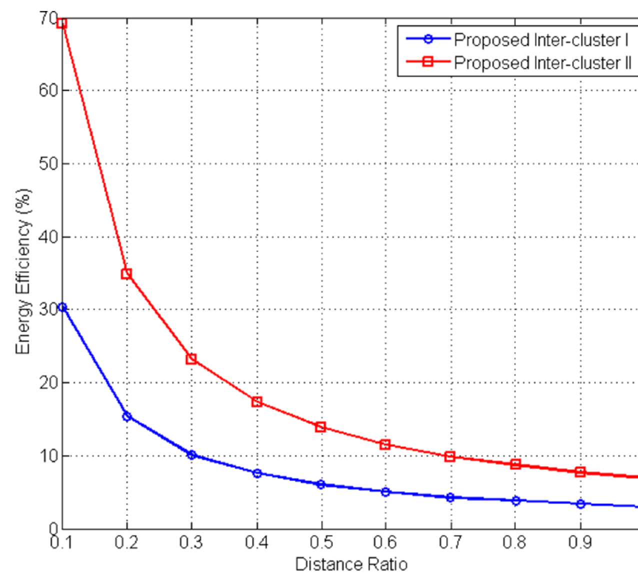

Fig. 8. Energy efficiency versus distance ratio for clustering cooperative D2D models.

C. Energy Efficiency

Energy efficiency was calculated by comparing the energy consumption of the proposed inter-clustering cooperative D2D models I and II to the energy consumption of the conventional multirelay-based D2D clustering system as a reference. As a result, computer simulations are run by computing the energy consumption in Eqs. (14), (19), and (21), respectively. Subsequently, Eqs. (22) and (23) simulate the energy efficiency for proposed models I and II, respectively. Finally, Figs. 7 and 8 illustrate the energy efficiency simulation results for proposed inter-clustering models I and II.

Figure 7 depicts the energy efficiency of the proposed inter-clustering cooperative D2D models I and II, with an average energy efficiencies of 36.5% and 54.2%, respectively, compared with the conventional model. Although the improved transmit power improved energy efficiency, it was not significant in either of the proposed models. However, the proposed inter-clustering cooperative D2D model II is more energy-efficient than the proposed D2D cooperative clustering model I. The network model affects the system's energy consumption because transmitting information from the relay to the destination is not forwarded by all relay nodes, but by the best relay node selected before the information is forwarded to the destination. It is generally believed that the greater the distance between the source and destination, the more energy is consumed, and vice versa.

Figure 8 depicts the simulation results of energy efficiency vs. distance for the two proposed models. The distance is expressed as a ratio, indicating that the longer the transmission distance, the higher is the energy consumption of both models. However, inter-clustering model II is more energy-efficient than inter-clustering model I because the source selects the optimal relay as the CH in forwarding information to the destination, thereby reducing the energy consumption in the network. However, inter-clustering model I requires more energy because the source transmits data to several neighboring relays to determine which relay is the best information forwarder to the CH. According to simulation results, the inter-clustering model II can save 10% energy compared to the inter-clustering model I at a distance ratio of 0.5. Inter-clustering Model II is the most energy-efficient and provides the highest throughput performance. Therefore, this model is well-suited for use in 5G overlay D2D and cellular communication systems.

V. CONCLUSIONS

We proposed two inter-clustering models using the proactive relay selection method in cooperative D2D networks and presented their corresponding algorithms. We then conducted a computer simulation to evaluate the OP performance, throughput, and energy efficiency of each proposed cooperative inter-cluster D2D model. Simulation results demonstrated that inter-clustering model II was supported by good link channel conditions and showed a low information transmission error rate. As a result, inter-clustering model II produced the lowest OP and highest throughput compared with inter-clustering model I and conventional clustering networks. Furthermore, inter-clustering model II was found to be more energy-efficient than inter-clustering model I because the source selects the optimal relay as the cluster head in forwarding information to the destination, thereby reducing energy consumption. Overall, inter-clustering model II improved OP performance by approximately 20%, increased throughput by 80 Kbps, and save 10% more energy compared with inter-clustering model I. These results demonstrate that inter-clustering model II is well suited for 5G overlay D2D and cellular communication systems.

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