Energy Efficient Relay Selection in Multi-hop D2D Networks

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***Abstract*—This paper studies energy-efficient relay selection schemes for cooperative multi-hop device-to-device (D2D) networks. D2D networks exploit proximity gain by establishing direct links between devices instead of relying on cellular links for communication. We consider a D2D network with random deployment of relay nodes between the source and the destination. The relay nodes are grouped into clusters, which act cooperatively to enhance network reliability. We derive received power and end-to-end transmission success probability expressions for a single-hop, two-hop and multi-hop network scenario assuming a Rayleigh fading channel and path loss. Further, we compare two relay selection schemes: i) random relay selection (RRS) and ii) Signal-to-noise ratio (SNR)-based relay selection (SRS) on the basis of energy-efficiency that provides a required quality of service (QoS).**

***Index Terms*—Multi-hop network, D2D, energy-efficiency, cooperative transmission.**

I. Introduction

The increasing number of mobile users has given impetus to the demand for high data rate proximity services. The fifth generation (5G) technology promises to improve the existing technology according to the future demands and provides a road-map for reliable and resource-efficient solution. Device-to-device (D2D) communication has been envisioned as an allied technology of 5G wireless systems for providing services that include live data and video sharing [1]. D2D communication technique opens new horizon of device-centric communications, i.e., exploiting direct D2D links instead of relying solely on cellular links. However, 5G D2D networks based on hand held devices have battery constraints, which augments the need for an energy efficient protocol.

Cooperative multi-hop D2D networks provide a platform for ensuring network longevity and enhanced end-to-end transmission success by conserving the resources and providing network diversity. Cooperative D2D networks are particularly helpful in disaster scenarios, where the basic power infrastructure is completely or partially destroyed. Authors in [2] provide an overview of a smart phone-based relay network for disaster scenarios. The system level architecture is discussed along with issues related to security, inter-connectivity and compatibility of D2D networks.

Similarly, [3] presents a comparison between network coding assisted multi-hop D2D communication, conventional base station (BS) assisted communication and a direct D2D communication with regards to energy efficiency. The analysis is limited to three D2D users scenario with fixed node distances. In our work in [4], a relay-aided network-coded (RANC) D2D network is analysed with respect to outage probability.

In this paper, we present a comparison between two relay selection schemes: i) random relay selection (RRS) and ii) Signal-to-noise ratio (SNR)-based relay selection (SRS). We conduct our analysis on a multi-hop network, where the relay nodes are randomly placed between the source and destination, as illustrated by Fig. 1. The random node deployment model provides a realistic analysis of D2D network with mobile D2D nodes. The relay nodes form clusters, which operate cooperatively for facilitating end-to-end connectivity. Rayleigh fading channel model is assumed with path loss, while the analysis of shadowing is left as a future direction to this work. We derive expressions for end-to-end success probability and explain the impact of relay selection schemes on overall energy consumption of the network. According to the best of our knowledge, no work has appeared in literature which presents a performance analysis for the aforementioned schemes in a multi-hop D2D network scenario. In this work, the deployment of multi-hop D2D network is discussed from a designer's perspective, highlighting performance tradeoffs between energy efficiency and the end-to-end transmission success.

The rest of the paper is organized as follows. Section II highlights related work on energy-efficiency in D2D networks. In Section III, D2D clustering and relay selection techniques are defined, followed by a discussion on transmission flow in Section IV, where Baye's law is employed in order to devise an analytical model of the end-to-end transmission success probability. Results and analysis are presented in Section V, and finally in Section VI we present our conclusions.

II. Related Work

Destruction of power transmission infrastructure in case of disasters gives rise to the need for energy efficient networks, which help in conserving the batteries of D2D users. Authors in [5] discuss energy efficient network setup for both uplink and downlink transmissions in a cooperative D2D network. The scheme is particularly useful in scenarios where live data sharing is desired among D2D users in close proximity.

5G networks comprising of hand held devices like smart phones have battery constraints which need to be taken into

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consideration. Energy efficient protocols can save battery time and ensure network longevity [6]. A special scenario of device-to-multidevice (D2MD) is considered in [7]. The proposed scheme aims at utilizing multiple transmit and receive antennas to exploit time gain. This scheme is applicable to cases where perfect channel state information (CSI) knowledge might not be available.

Another energy-efficient grouping approach for D2D is presented in [8]. D2D users, by sending beacon signals, communicate their locations to the other D2D users in proximity. Afterwards, each D2D user shares the latest locations of all D2D nodes with the group so that one particular node is not overloaded. The proposed scheme provides a scalable and energy efficient solution for D2D user grouping. Authors in [9] also present a joint clustering and power control scheme as a reliable and energy-efficient solution. In [10] a Distributed Power Control (DPC) scheme for conserving energy is discussed, which includes a power control mechanism along with Admission Control (AC). Similarly, a power control mechanism for an aerial BS assisted network is highlighted in [11], which is quite suitable for disaster scenarios.

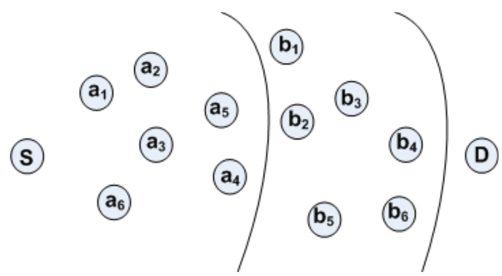


Fig. 1: Example of a D2D multi-hop cooperative network

III. D2D Clustering and Relay Selection

In this section, we discuss the architecture of the multi-hop D2D network, which consists of a source and a destination in addition to intermediate relays in between them. The relays cooperatively transmit the source message to the destination via a multi-hop mechanism. First, we discuss the BS-assisted clustering technique, where the source S initiates the clustering mechanism by broadcasting a probing signal. If the destination is able to decode the message in the first probing phase, it reports the received SNR back to the BS and a single-hop or direct D2D link is established between the source and the destination. In the case of a larger source-destination distance, the probing signal sent by the source is first received by the nodes in close proximity. The nodes that are able to decode the message report the received SNR values back to the BS and are identified by set $\mathbb{A} = \{a_i\}$ where $i = \{1, 2, \cdots n\}$. The BS groups these nodes into a cluster. A similar process takes place in the second probing phase, where the decode and forward (DF) nodes of set $\mathbb{A}$ concurrently broadcast the probing signal. Assuming perfect CSI, the receiver node combines all the received copies using maximal ratio combining (MRC)[1]. If the destination is able to successfully decode the message, it reports the received SNR to the BS and a two-hop D2D link is established between the source and the destination. Similarly, if the destination is inaccessible after the second probing phase, a third probing phase is initiated. For example, in the third probing phase, the nodes which successfully decode the message after post-detection combining of the message sent by nodes of set $\mathbb{A}$, share the received SNR with the BS and are grouped together as second cluster nodes identified by the set $\mathbb{B} = \{b_p\}$ where $j = \{1, 2, \cdots p\}$. In our study, we limit our analysis to a maximum of three hops, where cluster-based relay mechanism aids the transmission of message to destination.

Although, the clusters made by the BS can transmit the information forward, we propose two sub-clustering techniques, random relay selection (RRS) and SNR-based relay selection (SRS), where the relay nodes are selected in order to provide energy efficiency while maintaining a quality of service (QoS), which in our case is the end-to-end transmission success probability. We analyze the performance of RRS and SRS for different network parameters in terms of energy efficiency and end-to-end transmission success. The schemes are as follows:

A. Random Relay Selection (RRS)

In RRS, the BS chooses the relay nodes randomly from the DF nodes in a particular cluster. The node selection for transmission depends on the QoS parameter η, where η denotes the end-to-end success probability. We consider a multi-hop scenario, where the DF nodes in a cluster are known by the BS after the initial D2D clustering as mentioned earlier. Initially, the BS randomly chooses one node each from $\mathbb{A}$ and $\mathbb{B}$ to act as relays. The source transmits a test signal and the BS computes the end-to-end success. If QoS is met, the selected nodes are grouped as sub-clusters $\overline{\mathbb{A}}$ and $\overline{\mathbb{B}}$ by the BS, where $\overline{\mathbb{A}} \subseteq \mathbb{A}$ and $\overline{\mathbb{B}} \subseteq \mathbb{B}$. Otherwise, the iterative sub-clustering mechanism is continued until the desired η is ensured. For example, in next iteration, the size of $\overline{\mathbb{A}}$ is increased by one followed by an increment in the size of $\overline{\mathbb{B}}$ for the successive iteration. Although, this selection mechanism offers overhead because of successive iterations, however, we will show later that the method offers an energy-efficient solution by minimizing transmissions from relay nodes in a cluster. The minimum number of nodes that ensures the QoS is chosen for transmissions to minimize the overall energy consumption of the network.

B. SNR-based Relay Selection (SRS)

In SRS, the nodes which are positioned at a cluster edge are chosen as relays. The spatial distance between cluster edge nodes and the next hop nodes is less as compared to other nodes in a cluster, which provides substantial diversity gain due to the low path loss. The nodes at the cluster edge are identified by the fact that the edge nodes exhibit low average received SNR. In SRS, the BS sorts the node sets

[1]Note that any combining technique, e.g., equal gain combining (EGC) can also be used.

$\mathbb{A}$ and $\mathbb{B}$ in ascending order with respect to received SNR of the nodes. The sub clustering iterative mechanism for SRS is similar to RRS scheme with a difference that relay nodes in $\overline{\mathbb{A}}$ and $\overline{\mathbb{B}}$ are not chosen randomly. Instead, the nodes with the lowest received SNR are chosen first followed by other nodes from the sorted sets $\mathbb{A}$ and $\mathbb{B}$. The sub clustering mechanism continues until the QoS condition is ensured.

IV. Network Transmission Flow Model

In this section, we explain the transmission flow of the cooperative multi-hop D2D network. We divide our analysis into steps, deriving received power and success probability expressions for a single-hop, two-hop and multi-hop scenario.

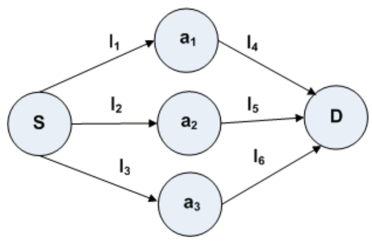


Fig. 2: Two-hop D2D network

A. One Hop D2D network

First, we consider a single hop scenario where a direct D2D link exists between the source and the destination. The source transmits the data with power P_t, whereas the power received at the destination node is given by

$$P_{r_{DS}} = \frac{P_t \mu_{SD}}{(d_{SD})^{\beta}}, \tag{1}$$

where the flat fading Rayleigh channel gain between source S and destination D is denoted by μ_{SD}, while the Euclidean distance between them is denoted by d_{SD}. The elements of μ are drawn from an exponential distribution with unit mean. The path loss exponent is represented by β with a normal range of 2-4. The destination is able to successfully decode the message if the received power is greater than a predefined threshold τ. The probability that the destination is able to decode the message is given by

$$\mathbb{P}\{Pr_{SD} \geq \tau\} = exp\{d_{SD}^{\beta}\tau\}, \tag{2}$$

where unit P_t is assumed.

B. Two-hop D2D network

For a dual hop D2D network, the transmission takes place in discrete time slots with source transmitting in the first time slot, r, followed by relays in the second time slot, $r+1$. Let $\mathbb{N}_r$ be the indices of nodes in the first hop cluster at time instant r, e.g., $\mathbb{N}_r = \{1, 2, 3\}$, as shown in Fig. 2. The received power and the probability analysis of first time slot resembles the single-hop case described in the previous section. The power received at any relay node of the first hop at time instant r is given by

$$Pr_{a_i S}^{(r)} = \frac{P_t \mu_{Sa_i}}{(d_{Sa_i})^{\beta}}, \tag{3}$$

where node index $i \in \mathbb{N}_r$.

Similarly, for second hop, the power received at the destination is given by

$$P_{r_D}^{(r+1)} = P_t \sum_{m \in \mathbb{D}_r} \frac{\mu_{a_m D}}{(d_{a_m D})^{\beta}}, \tag{4}$$

where $\mathbb{D}_r \subseteq \mathbb{N}_r$ is the set of nodes which have successfully decoded the message from the source. The probability density function (PDF) of the received power at destination depends on the number of nodes that have decoded the message in the first hop. If the cardinality of set $\mathbb{D}_r$ is unity, i.e., $|\mathbb{D}_r| = 1$, a single-input single-output (SISO) link exists between the relay and destination, while the outage expression is similar to (2). If $|\mathbb{D}_r| > 1$, a multiple-input single-output (MISO) link exists between the relay nodes and D, where the PDF of the received power at destination is given by hypo exponential distribution,

$$f_{P_{r_D}}(y) = \sum_{m \in \mathbb{D}_r} \lambda_{a_m} exp\{-\lambda_{a_m} y\} \prod_{k \neq m} \frac{\lambda_{a_k}}{\lambda_{a_k} - \lambda_{a_m}}, \tag{5}$$

where $\lambda_{a_m} = \frac{d_{a_m D}^{\beta}}{P_t}$. The success probability of the MISO link is then given as

$$\mathbb{P}\{P_{r_D}^{(r+1)} > \tau\} = \sum_{m \in \mathbb{D}} \prod_{k \neq m} \frac{\lambda_{a_k}}{\lambda_{a_k} - \lambda_{a_m}} exp^{-\lambda_{a_m}\tau}. \tag{6}$$

The end-to-end success probability for this two-hop network is modeled by conditional probabilities representing success and failure at the previous hop. We define a binary indicator random variable (RV) $\mathbb{I}_{a_i}$,which describes the status of a relay node such that

$$\mathbb{I}_{a_i} = \begin{cases} 0 & \text{if node fails to decode} \\ 1 & \text{if node successfully decodes.} \end{cases} \tag{7}$$

A set $\mathcal{X}^r = \{\mathbb{I}_{a_1}\mathbb{I}_{a_2} \cdots \mathbb{I}_{a_{|\mathbb{N}_r|}}\}$ denotes the state of the relay nodes at time instant r. We define a set $S^r = \{1, 2, 3, \cdots, 2^{(|\mathbb{N}_r|)} - 1\}$, where $S^r \subset \mathcal{X}^r$, denoting the decimal equivalent of the binary word formed by indicator random variables, e.g., $S^r = \{1, 2, 3, 4, 5, 6, 7\}$ for the topology shown in Fig. 2.

The total end-to-end success probability is computed using chain Bayes' law, i.e.,

$$\begin{aligned} P_{s_{total}D} &= P_{sD}|S^r(1)P(S^r(1)) + P_{sD}|S^r(2)P(S^r(2)) + \cdots \\ &\quad P_{sD}|S^r(7)P(S^r(7)) \\ &= \sum_{t=1}^{sup\{S^r\}} P_{sD}|S^r(t)P(S^r(t)), \end{aligned} \tag{8}$$

where $sup\{S^r\} = 2^{(|\mathbb{N}_r|} - 1)$, i.e., $sup\{S^r\} = 7$ for network topology of Fig. 2. $P(S(r))$ is denoted by a product of success and outage probabilities of SISO links between source and

TABLE I: MEAN ABSOLUTE ERROR BETWEEN THEORETICAL MODEL AND SIMULATION RESULTS

Absolute Error	$\widetilde{\tau} = 12dB$	$\widetilde{\tau} = 14dB$	$\widetilde{\tau} = 16dB$	$\widetilde{\tau} = 18dB$	$\widetilde{\tau} = 20dB$
Case 1:$\beta = 3, Pt_s = 1, Pt_{a_i} = \{1,1\}, Pt_{b_i} = \{1,1\}, d_1 = 0-2, d_2 = 0-4, d_3 = 0-4$	$4.5e^{(-3)}$	$4.2e^{(-3)}$	$2.5e^{(-3)}$	$1.6e^{(-3)}$	$6.6e^{(-4)}$
Case 2:$\beta = 2, Pt_s = 1, Pt_{a_i} = \{1,2\}, Pt_{b_i} = \{1,2\}, d_1 = 0-2, d_2 = 0-2, d_3 = 0-2$	$5.6e^{(-3)}$	$2.4e^{(-3)}$	$1.1e^{(-3)}$	$4.0e^{(-4)}$	$2.0e^{(-4)}$
Case 3:$\beta = 2, Pt_s = 1, Pt_{a_i} = \{1,2\}, Pt_{b_i} = \{2,2\}, d_1 = 0-4, d_2 = 0-6, d_3 = 0-6$	$1.9e^{(-2)}$	$1.7e^{(-2)}$	$1.1e^{(-2)}$	$5.8e^{(-3)}$	$2.5e^{(-3)}$
Case 4:$\beta = 2, Pt_s = 0.5, \quad Pt_{a_i} = \{0.5, 0.5\}, \quad Pt_{b_i} = \{0.5, 0.5\}, \quad (d_1, d_2, d_3) = 0-1$	$1.6e^{(-3)}$	$6.1e^{(-4)}$	$2.7e^{(-4)}$	$9.8e^{(-5)}$	$2.7e^{(-5)}$

relay nodes. For example, $P(S^r(4))$ signifies the state of relay nodes denoted by set $\mathcal{X}^r = \{100\}$ and $P(S^r(4)) = (Ps_{Sa_1} Po_{Sa_2} Po_{Sa_3})$, where $Ps_{Sa_i} = (\mathbb{P}\{Pr_{SD} \geq \tau\})$ and $Po_{Sa_i} = (1 - \mathbb{P}\{Pr_{SD} \geq \tau\})$.

C. Multi-hop D2D Network

In our analysis for multi-hop D2D network we consider a three hop D2D network, where the transmissions between source and destination take place in three discrete time slots. The expressions of received power and the PDF of received power at first hop nodes are similar to the expressions defined in Section II-B. The total success probability between the source and second hop nodes is defined as

$$P_{s_{total} b_j} = \sum_{t=1}^{sup\{S^r\}} P_{sb_j} | S^r(t) P(S^r(t)), \tag{9}$$

where $j \in \mathbb{N}_{r+1}$.

The total end-to-end success probability at destination D is given by,

$$P_{s_{total} D} = \sum_{t=1}^{sup\{S^{r+1}\}} P_{sD} | S^{r+1}(t) P(S^{r+1}(t)) \tag{10}$$

where $S^{r+1} \subset \mathcal{X}^{r+1}$ and $\mathcal{X}^{r+1} = \{\mathbb{I}_{b_1} \mathbb{I}_{b_2} \cdots \mathbb{I}_{|\mathbb{N}_{r+1}|}\}$. For example, if $\mathcal{X}^{r+1} = \{010\}$ then $P(S^{r+1}(t)) = ((1 - P_{s_{total} b_1})(P_{s_{total} b_2})(1 - P_{s_{total} b_3})$.

V. RESULTS AND ANALYSIS

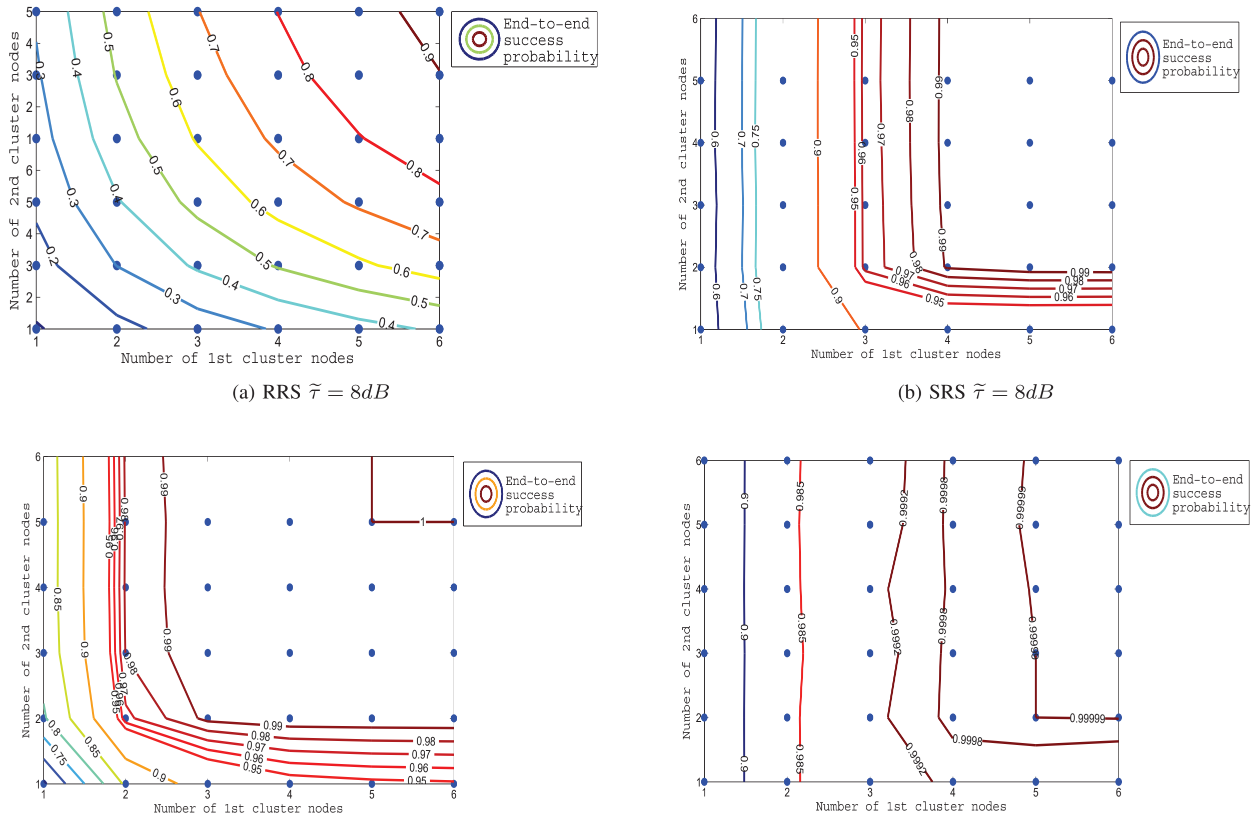
In this section, we present the numerical results with respect to different performance metrics. First, a comparison of theoretical and simulation results is presented to ascertain the validity of the proposed scheme. The transmission flow of simulation model is defined in Algorithm 1. An equal transmit power of unity is assumed for all nodes in the network. The source to destination distance varies for different cases. The distances d_1, d_2, d_3 specify the distance ranges for random deployment of nodes between (S to a_i), (a_i to b_j) and (b_j to D) respectively, i.e., $d_1 = 0-2$ means that the first cluster nodes a_i would be distributed randomly within a distance of 0-2 from the source. Similarly, the relay nodes in second cluster are also randomly distributed within the distance range d_2. We also define a notion of normalised threshold, as $\widetilde{\tau} = 10 log \frac{1}{\tau}$. The end-to-end success probability is computed for random node locations, which is averaged out by conducting Monte Carlo trials. The mean absolute error (MAE) between theoretical and simulation results for different network parameters when applied to the multi-hop network is shown in Table I, which shows a close agreement between the simulation and theoretical models.

Algorithm 1 End-to-end Transmission Success

1: **Phase 1: State of nodes at time** r**,**
2: Compute $P_{r_{a_i S}}$ for i=1 to n
3: **if** $P_{r_{a_i S}} > \tau$ **then**
4: Set Indicator random variable (RV) $\mathbb{I}_{a_i} = 1$ **else** $\mathbb{I}_{a_i} = 0$
5: Continue process and save Indicator RV in $\mathcal{X}^{(r)}(i)$
6: **end if**
7: **if** $\mathcal{X}^{(r)} = 0$ **then**
8: **Output** Failure **END Transmission**
9: **else**
10: Continue to Phase 2
11: **end if**
12: **Phase 2: State of nodes at time** $r+1$
13: Compute $P_{r_{b_j total}} = \sum_{i=1}^{k} P_{r_{b_j a_i}} \mathbb{I}_{a_i}$ for j=1 to p
14: Repeat Steps 3 and 4 for $P_{r_{b_j total}}$ and save Indicator RV in $\mathcal{X}^{(r+1)}$.
15: **if** $\mathcal{X}^{(r+1)} = 0$ **then**
16: **Output** Failure **END Transmission**
17: **else**
18: Continue to Phase 3
19: **end if**
20: **Phase 3: State of nodes at time** $r+2$
21: $P_{r_{D total}} = \sum_{k=1}^{m} P_{r_{D b_k}} \mathbb{I}_{b_k}$
22: **if** $P_{r_{D(r+2)}} > \tau$ **then**
23: **Output:** Success
24: **else**
25: **Output:** Failure
26: **end if**

In Fig. 3, a comparison of RRS and SRS is presented on the basis of end-to-end success probability, for two values of normalized threshold, i.e., $\widetilde{\tau} = 8dB$ and $14dB$ for different combinations of first and second cluster relay nodes. In our analysis, the total number of relay nodes initially selected by the BS, in both clusters, is six with a source to destination distance of 10. For a successful transmission, QoS parameter $\eta \geq 0.9$ is assumed, i.e., we require that the destination decodes the message with a success probability of at least 90%. For ease of analysis, we refer to the combination of first and second cluster nodes as (i, j), where (1,2) means one node from first cluster and two nodes from second cluster participate in the transmissions. The energy consumption for end-to-end transmission in RRS and SRS schemes for combinations (i, j) is shown in Fig. 4, where the magnitude of energy consumed in dB is represented by the color bar in the figures.

Fig. 3(a) highlights the performance of the RRS at $\widetilde{\tau} = 8dB$. It can be seen that only combinations (6,5) and (6,6) provide



(a) RRS $\widetilde{\tau} = 8dB$

(b) SRS $\widetilde{\tau} = 8dB$

(c) RRS $\widetilde{\tau} = 14dB$

(d) SRS $\widetilde{\tau} = 14dB$

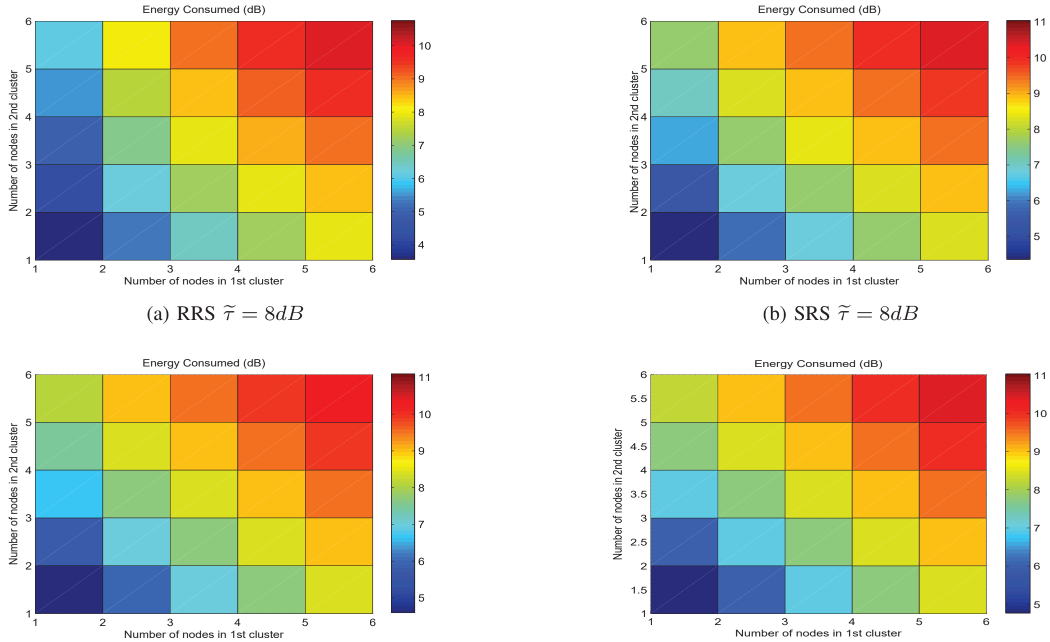
Fig. 3: QoS comparison between RRS and SRS

the desired QoS while the lowest average energy consumption of $10dB$ is observed for combination (6,5) as shown by Fig. 4(a). On the other hand, Fig. 3(b) shows that the SRS scheme ensures the QoS at several combinations with lower node participation than the RRS scheme, e.g., combinations (3,1) and (3,2) provide the required QoS. It is pertinent to note that the lowest energy consumed by SRS scheme for maintaining the QoS is $6dB$ for (3,1) combination, which signifies an energy saving of 60% when compared to (6,5) combination of RRS scheme with $10dB$ energy consumption. Also, it can be seen that the sub-clustering schemes, RRS and SRS, help in conserving energy when compared to the conventional multi-hop transmission where all DF nodes in a cluster participate in transmission. For $\widetilde{\tau} = 8dB$, SRS combination (3,1) provides maximum energy saving of 68% when compared to energy consumption of $11dB$ by the conventional (6,6) combination.

A similar trend is observed for $\widetilde{\tau} = 14dB$, where the SRS scheme ensures QoS at lower node participation than RRS scheme. Here again the SRS outperforms RRS by providing energy saving of 20%, as SRS ensures QoS for combination (2,1) with $5dB$ energy consumption, while in RRS scheme the QoS criteria is fulfilled for combination (3,1) with $6dB$ energy consumption. As mentioned earlier, the clustering mechanism can formulate a single-hop, two-hop or a multi-hop network, depending on the QoS criteria and network parameters such as distance and path loss exponent. The aforementioned analysis highlights the performance of SRS and RRS in a multi-hop scenario. Now we analyze the performance of a single-hop and two-hop network for same network parameters at $\widetilde{\tau} = 14dB$ to ascertain the optimal network topology from a designer's perspective.

A. *One-hop Transmission*

With source-destination distance at 10, and $\widetilde{\tau} = 14dB$, an average end-to-end success of only 18% is achieved for a source transmit power $P_t = 1$. For $P_t = 10$, the end-to-end success of 67% is achieved even though the source utilizes $5dB$ more power as compared to optimal SRS combination (2,1) for a multi-hop scenario with energy consumption of $5dB$. This shows that the desired QoS cannot be ensured a direct link. Furthermore, a higher source transmit power seems impractical for a D2D network whereas on the contrary, a multi-hop network topology can be employed in order to distribute the transmission load among relays for network longevity.



(a) RRS $\widetilde{\tau} = 8dB$

(b) SRS $\widetilde{\tau} = 8dB$

(c) RRS $\widetilde{\tau} = 14dB$

(d) SRS $\widetilde{\tau} = 14dB$

Fig. 4: Energy consumption comparison between RRS and SRS

B. Two-hop Transmission

For RRS scheme, the QoS is ensured by participation of three nodes from the cluster with a total energy consumption of $5.1dB$. However, for SRS scheme, the desired QoS is ensured by participation of two nodes from the cluster with average energy consumption of $3dB$, which is lower than the energy consumed by multi-hop SRS combination (2,1). Based on these results we can conclude that for $\widetilde{\tau} = 14dB$, two-hop D2D network provides the optimal solution with regards to energy consumption.

VI. Conclusion

In this paper, we have provided a comparison of two relay selection schemes RRS and SRS for a multi-hop D2D network in terms of energy efficiency and end-to-end transmission success. The network model comprises of random deployment of relay nodes between the source and the destination, where the nodes are grouped to form clusters. We analyzed the received power and success probability expressions for a single-hop, two-hop and a multi-hop scenario. It has been shown that SRS scheme provides enhanced end-to-end success by exploiting the proximity gain between devices. We also quantify energy consumption of both schemes and highlight the energy saving achieved through sub-clustering mechanisms.

Acknowledgment

This research work was supported in part by the Erasmus Mundus LEADERS Doctorate Level Mobility program, funded by the European Union.

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