

Modified Clusterhead Selection Technique for Efficient Resource Allocation in Multi-Device-to-Device Cluster Multicast Communications in Cellular Networks

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ABSTRACT

This study is primarily centered on enhancing the precision of route selection for Device-to-Device (D2D) communication by focusing on the optimal selection of D2D devices. In pursuit of this objective, a novel approach has been developed, termed as the "Modified Clusterhead Selection Technique." This technique is specifically designed to optimize resource allocation in the context of multiple Device-to-Device Cluster (D2DC) multicast communications within cellular networks. The modification incorporated into the clusterhead selection technique takes into meticulous consideration the processing capacity of D2D devices. This strategic enhancement aims to mitigate network congestion, thereby contributing to the amelioration of network data rates and bolstering overall energy efficiency. By prioritizing the optimization of resource allocation and introducing modifications to the clusterhead selection process, this research endeavors to address critical issues associated with D2DC multicast communications in cellular networks. The overarching goal is to enhance the reliability and efficiency of these communications by minimizing congestion, thereby promoting superior data rates and energy conservation.

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INTRODUCTION

The spontaneous growth in high data consuming devices in telecommunications networks, necessitates need to provide increased network capacity [1]. The introduction of D2D communication concept sharing the same resources allocated to cellular users (CUs) makes it possible for cellular networks to accommodate more users in their networks. But it happens that these accommodated users often demand the same data resources simultaneously [2]. To satisfy their data demand, multicast communication concept was introduced. Multicasting in D2D communication involves the transfer of same data packets from a CH to multiple D2D receivers [3].

In [9] a modified resource allocation for multiple device-to-device cluster multicast communications underlying cellular networks was

developed by considering the processing capacity of intermediate devices during multicast data dissemination. This was done to ensure that efficient routing path is used for data dissemination.

This work is aimed at improving the data rate and energy efficiency of all the clusters in the cell, by evaluating the processing capacity of a clusterhead (CH) devices during clusterhead selection, so as to ensure that efficient routes are discovered and used during data dissemination. This will ultimately translate to enhance data rate and energy efficiency of the network.

LITERATURE REVIEW

Reviews of similar works that are pertinent to this study are as follows:

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[9] A modified resource allocation for multiple device-to-device cluster multicast communications underlying cellular networks was developed by considering the processing capacity of intermediate devices during multicast data dissemination. This was done so as to ensure sufficient data throughput.

[4] Developed a resource allocation scheme for multiple D2DC multicast communications underlying cellular networks by using partial information of the device locations. Their scheme was developed by using partial information of device location (PIDL) instead of full information. This was done to reduce network overhead during route search in the network and used outage probability to allocate resources. [6] Developed a traffic offloading in multicast device-to-device cellular networks and a combinatorial auction-based matching algorithm to improve data rate and energy efficiency of the network. They use fractional frequency reuse (FFR) in sharing

the resources, lagrangian relaxation technique (LRT) to solve non-convex optimization issues. But, using lagrangian relaxation technique means that it will take longer period to deliver data resources to the users.

[8] Proposes a resources allocation and power control based on non-cooperative game for D2D communication underlay cellular network. An algorithm that combines the spectrum allocation and power control to solve the problem of the throughput maximization in device-to-device communication systems.

METHODOLOGY

D2DC System Model

The system model used in [9] will be adopted for the course of this research work. The D2DC multicasting involves the transfer of data packets from a CH to multiple receivers in the cluster [4].

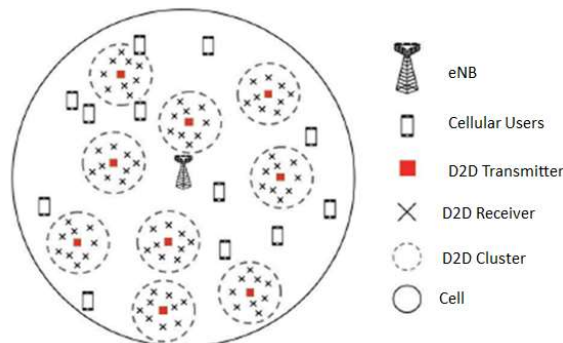


Figure 1: D2DC Cellular Network Representation [9]

Traditionally, multicasting is only allowed in underlay cellular network using cellular channels, provided it does not violate the required cellular outage probability stipulated by the network [9]. This entails that the transmit power of the D2D devices must be equal to or below the transmit power of CUs [9]. Therefore, $P_{DTx} \leq P_{CU}$, where P_{DTx} is the power allocated to the D2D device while P_{CU} is the power allocated to the CUs by the eNB [9]. The outage probability for Channel Allocation using Partial Information of device Location (CA-PIL) as used by [9] is given as:

$$\rho_t^j \approx \Pr \left\{ \frac{1}{N_t} \sum_{n=1}^{N_t} R_{tn}^j < R_{tgt} \right\} \quad (1)$$

where: N_t is the total number of DR_x in cluster t . R_{tn}^j is the rate of DR_x n in cluster t over channel j . R_{tgt} is the target rate.

When considering an asymptotic case where N_t is

large, $\frac{1}{N_t} \sum_{n=1}^{N_t} R_{tn}^j$ converges to Gaussian random variable with mean μ_t^j and variance

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$(\sigma_t^j)^2$. Thus, when considering large N_t , ρ_t^j is further approximated as [9]:

$$\rho_t^j \approx \rho_t^{-j} \left[1 - Q \left(\frac{R_{igt} - \mu_t^j}{\sigma_t^j} \right) \right] \quad (2)$$

The outage of D2DC t in the situation where average rate of transmission from the transmitting D2D device to $N_t R_{D_x}$ is below the target rate. The outage probability of cluster t over channel j is given as:

$$\rho_t^j \approx \Pr \left\{ \frac{1}{N_t} \sum_{n=1}^{N_t} \log_2 (1 + \gamma_{tn}^j) < R_{igt} \right\} \quad (3)$$

where γ_{tn}^j is the received signal at R_{D_x} in cluster t over channel j .

$$R_{igt} = \log_2 (1 + \gamma_d) \quad (4)$$

The effective throughput (ET) of cluster t over channel j is given as: $ET = R_{igt} (1 - \rho_t^j)$ (5)

The cost function used by [4] is given as:

$$CF_{CA-PIR} = \left\{ \rho_t^j \right\} \quad (6)$$

The data rate is a metric used to define the successful transmission of information on the network. The data rate between D2D device and the cellular users helps in determining the system performance. The SINR achieved by D2D devices as used by [6] is:

$$\gamma_m^j = \frac{P_t^m H_{mc}}{\sigma_w^2 + \delta_{c,m}^j P_t^m H_{mc} + \sum_{i \neq m, i \in M} \delta_{c,m}^i P_t^i H_{m,m}} \quad (7)$$

Where:

P_t^m represent the transmit power of multicast D2D group m .

$H_{m,c}$ is the channel gain between multicast D2D group m and cellular user c .

σ_w^2 denote the noise spectral density.

$\delta_{c,m}^i$ stands for a binary variable to represent resource allocation.

$\sum_{m \neq m, m \in M} \delta_{c,m}^i P_t^m H_{m,m}$ is the interference coming from co-channel D2D users.

The data rate achieved by D2D devices as used by [6] is:

$$R_m^i = \log_2 (1 + \gamma_m^i) \quad (8)$$

The energy efficiency of cellular network is of paramount importance in determining the performance of the network. The amount of information that can be successfully transmitted per joule of the consumed energy. The energy efficiency is defined as the ratio of the transmitted data and the energy consumed in doing so. This is given as used by [6]:

$$E_{eff} = \frac{T_d}{P_t^j} \quad (9)$$

Where T_d and P_t^j denote the transmitted data and transmit power of D2D device over channel j respectively.

The modified clusterhead selection technique for multiple D2DC

For the purpose of this research, the scheme used in [9] will be adopted.

Developing a modified clusterhead selection technique for optimum resource allocation scheme for multiple D2DC multicast communications underlying cellular networks by using the following Steps:

- a) Initializing the circular-shaped single cell with multiple D2D devices.
 - b) Determining the locations of cellular users and D2D transmit device by the eNB.
 - c) Determining distance between cellular users CU and D2D transmit device by the eNB.
 - d) ρ^k_B denote the outage probability of the link
 - e) Estimate the threshold for defining the outage of D2D links
 - f) Determining the processing capacity of intermediate D2D devices along routes with the lowest outage probability.
 - g) Allocating channels between CUs and D2DC devices along paths with least outage probability and having intermediate nodes with highest processing capacity.
1. The performance of the modified clusterhead selection technique will be validated with the work of [6] using data rate and energy efficiency as performance metrics.

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Selection of clasterheads among D2D Device with the Lowest Outage Probability and the highest processing capacity

This work takes into consideration the processing capacity of intermediate devices during clasterhead selection among devices within the clusters in a cell just as used by [9]. The processing capacity is achieved using the following equation:

$$\text{Processing Capacity} = \frac{\text{Packet Size in Buffer}}{\text{Buffer Size}} \quad (10)$$

The packet size in the buffer is obtained using the following equation [9]: Packet Size in Buffer = $\frac{\text{Input Queue Length} - \text{Output Queue Length}}{t}$ (11)

$$P_{cap} = \frac{P_{sb}}{B_s} = \frac{\frac{Q_{in} - Q_{out}}{t}}{B_s} \quad (10b)$$

$$P_{cap} = \frac{Q_{in} - Q_{out}}{B_s t} \text{ (Hz)} \quad (12)$$

Also the input queue length and output queue length are obtained using equations (13) and (14) respectively [10]:

$$Q_{in} = L_q = \frac{\rho^2}{1 - \rho} \quad (13)$$

$$Q_{out} = W_q = \frac{L_q}{\lambda} \quad (14)$$

Where:

L_q is the mean number of packets in the queue.

ρ represent the utilization of the server

W_q stands for the mean waiting time in the queue.

λ is the mean arrival time of the packets.

Therefore, the costs function as used by [9]:

$$iCF_{CA-PIR} = \{ \rho_t^j, P_{cap} \} \quad (15)$$

$$iCF_{CA-PIR} = \left\{ \rho_t^j, \frac{Q_{in} - Q_{out}}{B_s t} \right\} \quad (16)$$

where: P_{cap} is the processing capacity

P_{sb} is the packet size in the buffer

B_s is the buffer size

Q_{in} is the input queue length

Q_{out} is the output queue length

t is time

The D2D threshold for the processing capacity (P_{th}) as used by [9]:

$$P_{th} = \frac{\sum^T P_{cap}}{N_t} \quad (17)$$

The ClasterHead selection between CUs and D2DC Devices along Paths with Least Outage Probability and with Highest Processing Capacity.

The multicasting of data from the CH is done over channel j . The selection of D2D device with optimum properties is needed for better network data rate and energy efficiency in an optimized resources Allocation scheme for multiple D2DC multicasts underlying cellular networks. The probability of selecting a D2D device with optimum processing capacity for transmission purpose is given as [9]:

$$P_{cap}^j = \Pr(P_{cap} \leq P_{th}) \quad (18)$$

$P_{cap} = 1$ Implies that the D2D device is selected for transmission and $P_{cap} = 0$ otherwise.

Therefore, the optimization problem is given as [9]:

$$\left. \begin{aligned} & \max_{\delta_t^j \in (0,1)} \sum_{t=1}^T \sum_{j=1}^J \delta_t^j [R_{igt}(1 - \rho_t^j), P_{cap}^j] \\ & C_1 : \sum_{j=1}^J \delta_t^j \leq 1, \forall_t = 1, \dots, T \\ & C_2 : \sum_{t=1}^T \delta_t^j \leq 1, \forall_j = 1, \dots, J \\ & C_3 : \sum_{t=1}^T \sum_{j=1}^J \delta_t^j \leq \min(J, T) \\ & C_4 : \sum_{t=1}^T P_{cap} \leq P_{th}, \forall_t = 1, \dots, T \end{aligned} \right\} \quad (19)$$

for optimizing equation (19), The $mCST$ (modified clasterhead selection technique) uses ρ_t^j in equation (1) with ρ_t^j in equation (2) just as used in [9]. The flowchart for $mCST$ is given in Figure 2.

Figure 2 shows the Flowchart of the $mCST$ Algorithm.

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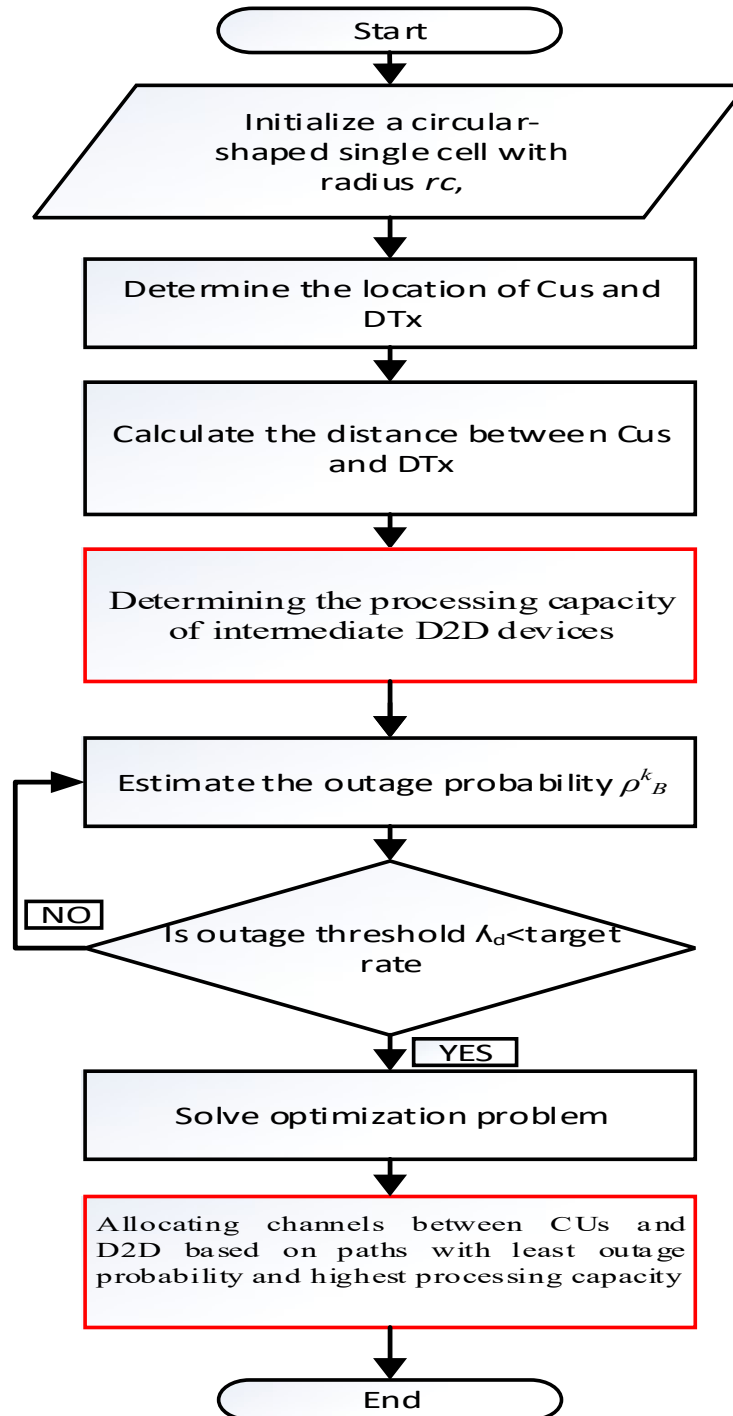


Figure 2: The Flowchart for mCST

Table 1: Simulation Parameters

Parameter	Value
Simulator	MATLAB 2018
The simulator	
Cell radius	500m
Variance of Gaussian random variable	-140 dBm
Path loss exponent	3.5
Cellular link outage threshold	5 dBm
D2D link outage threshold	5 dBm
Maximum transmit power of t transmitter	23dBm
Maximum transmit power of D2D transmitter	15dBm
Buffer size B (packet)	10
Packet size	100 bits

RESULTS AND DISCUSSION

Here, various result obtained through simulations are presented and discussed accordingly.

Data Rate versus Number of Iteration

Figure 3 shows a graph of data rate at different iterations during simulation for both [6] and m CST scheme. From the Figure, it was

observed that the developed scheme showed better higher data rate than the [6] scheme.

This is due to the consideration of outage probability and D2DC device processing capacity that enables successful transmission of data to D2D receivers. Equation (8) was used in calculating the data rate of the network. Hence, the performance of m CST during communication is practicably more efficient.

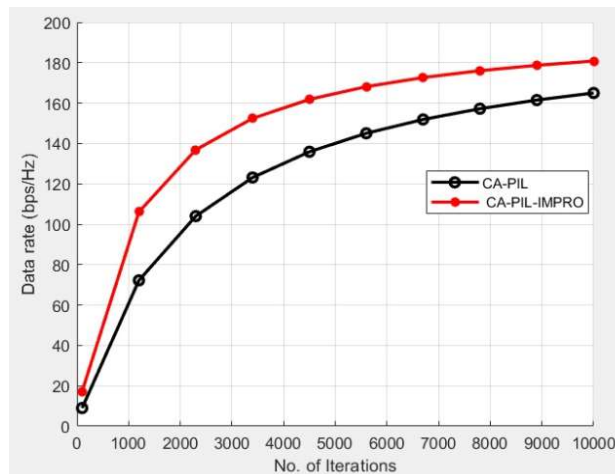


Figure 3: Plot of Data Rate versus Number of Iterations

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Energy Efficiency versus D2DC Size

The energy efficiency of the network determines the network lifetime. Figure 4 shows the energy efficiency of D2D cluster sizes for both [6] and *mCST*. From the graph, it was observed

that as the cluster size increases, the energy efficiency of the network decreases.

This is due to the increase in energy demand by D2D transmitters. The available network energy designed for data transmission is probably shared by D2DC.

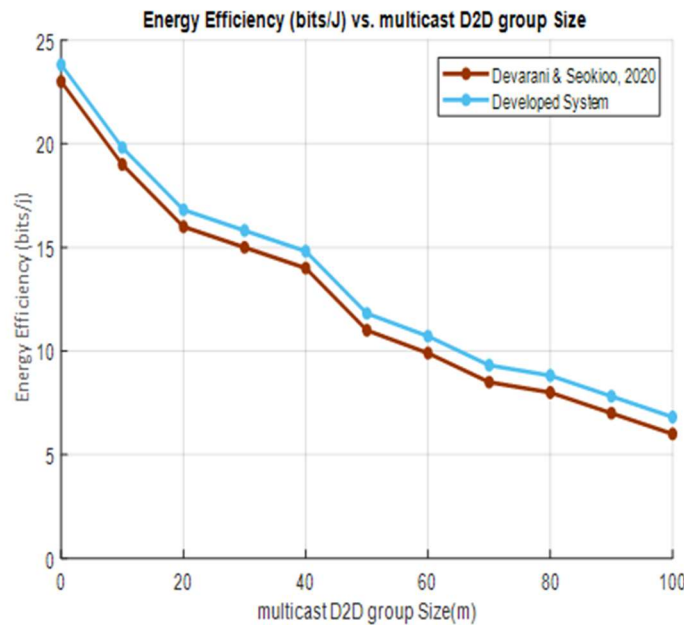


Figure 4: Plot of Energy Efficiency versus D2DC Size

CONCLUSION

From the results obtained it was summarized that the modified clusterhead selection technique (*mCST*) performs better in terms of data rate and energy efficiency. *mCST* scheme is efficient as it provides a practicable algorithm that improves the data rate and energy efficiency of the cellular network.

The *mCST* performs better than the [6] as the processing capacity and outage probability of D2DC devices was considered in the design algorithm. The developed scheme mitigates the possibility of having inefficient routing paths used for data dissemination. Magnanimous emulate

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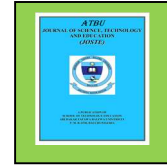
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