A modified resources allocation scheme for multiple D2D cluster multicast communication underlay Cellular Network

Uchenna N. Chikeluba[1], Mohammed D. Almustapha[2], Abdumalik S. Yaro [3] and Monday F. Ohemu[4]

[1, 2, 3] Department of Telecommunications Engineering Ahmadu Bello University, Zaria

[4]Department of Electrical and Electronics Engineering, Airforce Institute of Technology, Kaduna

Abstract: **The continuous growth in the number of mobile users in wireless networks necessitates the need for increased network capacity as well as data dissemination to these users simultaneously. Device-to-Device (D2D) communication provides a way of accommodating more users in the networks, while multicast communication makes it possible to transmit data from a source to multiple destinations. A prominent problem in the multicast of data disseminated from the CH to multiple devices in wireless networks is the high probability of inefficient routing paths used for data dissemination. This results in retransmission, which could lead to outage and unnecessary overhead, as well as negatively affecting the network effective throughput. To mitigate this problem, this research considers the processing capacity of intermediate devices for the multicast of data in the D2DC, in order to resourcefully create efficient routing paths and maintain seamless dissemination of data in the underlay cellular networks.**

Key Words: **Cluster, D2D, Multicast, Outage probability, Effective throughput, Processing capacity, Resources allocation.**

I. INTRODUCTION

With the continuous growth of connected devices in telecommunications networks, the need to provide increased capacity remains a major aim to be realized **[1]**. The introduction of D2D communication utilizing the already assigned spectrum allocated to cellular users (CUs) has enabled the accommodation of more users into cellular networks. It frequently happens that these increasing numbers of users often request the same data simultaneously **[2].**To meet this demand, multicast communication is adopted. In D2D scenario, multicast D2D communication involves the transfer of data packets from a CH to multiple receivers **[3].** In **[4]**, a resource allocation scheme for multiple device–to-device clusters (D2DC) multicast communications were developed. This scheme worked by selecting cluster heads (CHs) that collect common data from the evolved NodeB (eNB) via multicast communication. The CHs then transmit the data to multiple devices in their clusters using D2D communication.

This work therefore is the development of a modified resource allocation for multiple device-to-device cluster multicast communications underlying cellular networks by considering the processing capacity of intermediate devices during multicast data dissemination. This was done so as to avoid and overcome the challenge of data retransmissions flooding the network and causing congestion which ultimately results in reduced quality of service (QoS) for the cellular users (CUs) as packets will be dropped.

II. LITERATURE REVIEW

Some work have been done in this area which include the following:

[5] Proposes Energy efficient D2D communication-based retransmission scheme for reliable multicast in wireless cellular network. This scheme focuses on the multicast from BS to a cluster of nodes which are close to one another and design efficient D2D communication-based retransmission scheme. As the total available channel is quite limited in wireless cellular network (WCN), they consider the design of D2D communication based retransmission scheme where all re-transmitters use the same channel (rather than multiple channels) in Time division multiple access (TDMA) mode. Using TDMA in the resource allocation process means longer time will be taken to efficiently allocate resources to users.

[4] Developed a resource allocation scheme for multiple D2DC multicast communications underlying cellular networks by using partial information of the device locations. A channel allocation scheme was developed by making use of the partial information of the device locations. However, there still exists the problem of overhead messages during data transmission as paths discovered using partial information were inefficient, resulting in retransmissions of data which led to congestion.

[6] Proposed a traffic offloading in multicast device-to-device cellular networks: a combinatorial auction-based matching algorithm. . In the paper they consider a fractional frequency reuse (FFR) technique which divides the whole spectrum into multiple sections and allows reusing of spectrum resources between cellular users and multicast D2D users in a non-orthogonal scenario. To solve the non-convex issue in optimization, they introduce the lagrangian relaxation technique (LRT) and combinatorial auction-base matching algorithm to select the most desirable resource reuse partners. Computational complexity of the system increase with the increase in the number of users.

[8] Proposes a distributed resources allocation algorithm that combines the spectrum allocation and power control to solve the problem of the throughput maximization in device-to-device communication systems. Their work was able to improve the throughput of the D2D underplaying communication system. However, the computational complexity of the system increases with the increase in the number of users.

III. METHODOLOGY

3.1. D2DC System Model

For the purpose of this research, the system model used in [4] will be adopted. The D2DC is defined as a multicast cluster where common data is transferred via multicasting from a cluster head (CH) or D2D transmitter (DT_x) to multiple D2D devices underlying the cellular network [4].

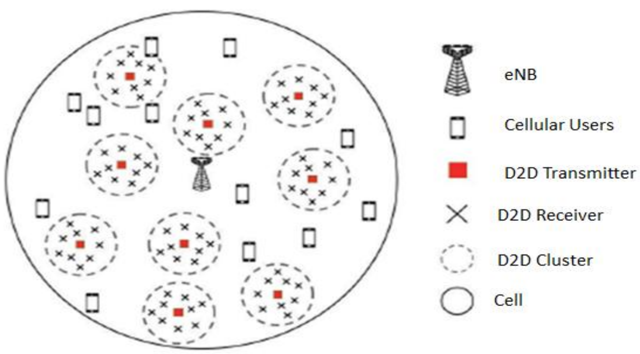


Figure 1: D2DC Cellular Network Representation [4]

The D2DC is only allowed to multicast in underlay cellular networks, using cellular channels, provided it does not violate the required cellular outage probability that is assumed to be prefixed in the cellular network [4].This will require that the transmit power of the D2D devices must be equal to or below the transmit power of CUs [4]. Thus, $P_{DTx} \leq P_{CU}$, where P_{DTx} is the power allocated to the D2D device while D_{CU} is the power allocated to the CU by the eNB [4]. The outage probability for Channel Allocation using Partial Information of device Location (CA-PIL) as used by [4] is given as:

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

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, $\frac{1}{N_t} \sum_{n=1}^{N_t} \bar{R}_{tn}^{j}$ converges to Gaussian random variable with mean μ_t^j and variance $\left(\sigma_t^j\right)^2$. Thus, when considering large N_t, ρ_t^j is further approximated as [4]:

$$\rho_t^j \approx \bar{\rho}_t^j \triangleq 1 - Q\left(\frac{R_{tgt} - \mu_t^j}{\sigma_t^j} \right) \qquad (2)$$

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

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

where γ_{tn}^j is the received signal at $R_{D_{Tx}}$ *n* in cluster *t* over channel *j*.

$$R_{tgt} = \log_2\left(1 + \gamma_d\right) \qquad (4)$$

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

The cost function used by [4] is given as: $CF_{CA-PIR} = \left\{\rho_t^j\right\}$ (6)

3.2. *Improved resource allocation scheme for multiple D2DC*

Developing the improved 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.

2 Comparing the performance of the proposed resource allocation scheme with the resource allocation scheme from [4] using effective throughput, energy efficiency and data rate as performance metric.

3.3. Processing Capacity of Intermediate D2D Devices along Routes with the Lowest Outage Probability

This research work proposes to consider the processing capacity of intermediate devices during the multicast dissemination of data among users within clusters in a cell. The proposed processing capacity that will be used is obtained using the following equation [7]:

Processing Capacity = $\frac{\text{Packet Size in Buffer}}{\text{Buffer Size}}$ (7a). Where the packet size in the buffer is obtained using the following equation [5]: Packet Size in Buffer = $\frac{\text{Input Queue Length} - \text{Output Queue Length}}{\text{Time}}$ (8)

$$P_{cap} = \frac{P_{sb}}{B_s} = \frac{\frac{Q_{in} - Q_{out}}{t}}{B_s} \quad (7b)$$

$$P_{cap} = \frac{Q_{in} - Q_{out}}{B_s\, t} \; (Hz) \quad (9)$$

Therefore, the costs function of the proposed work:

$$iCF_{CA-PIR} = \left\{ \rho_t^j, P_{cap} \right\} \quad (10)$$

$$iCF_{CA-PIR} = \left\{ \rho_t^j, \frac{Q_{in} - Q_{out}}{B_s t} \right\} \quad (11)$$

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}) is given as:

$$P_{th} = \frac{\sum_{t}^{T} P_{cap}}{N_t} \quad (12)$$

3.4 Channels Allocating between CUs and D2DC Devices along Paths with Least Outage Probability and with Highest Processing Capacity.

The multicasting of data in underlay cellular network is done over channel *j*. The selection of D2D device with optimum properties is needed for better network ET in improved Channel Allocation using Partial Information of device Location (iCA-PIR). The probability of selecting a D2D device with optimum processing capacity for transmission purpose is given as:

$$P_{capt}{}^{j} = \Pr\left(P_{cap} \le P_{th}\right) \quad (13)$$

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

Hence, the improved form of the optimization problem is given as:

$$\left.\begin{aligned} &\max_{\delta_t^j \in (0,1)} \sum_{t=1}^{T} \sum_{j=1}^{J} \delta_t^j \left[R_{tgt}\left(1-\rho_t^j\right), P_{capt}{}^{j} \right] \\ &C_1 : \sum_{j=1}^{J} \delta_t^j \le 1, \ \forall_t = 1,\ldots,T \\ &C_2 : \sum_{t=1}^{T} \delta_t^j \le 1, \ \forall_j = 1,\ldots,J \\ &C_3 : \sum_{t=1}^{T} \sum_{j=1}^{J} \delta_t^j \le \min\left(J,T\right) \\ &C_4 : \sum_{t=1}^{T} P_{cap} \le P_{th}, \ \forall_t = 1,\ldots,T \end{aligned}\right\} \quad (14)$$

The iCA-PIL uses ρ_t^j in equation (1) with ρ_t^j in equation (2) for optimizing equation (14). The flowchart for iCA-PIL is given in Figure 2

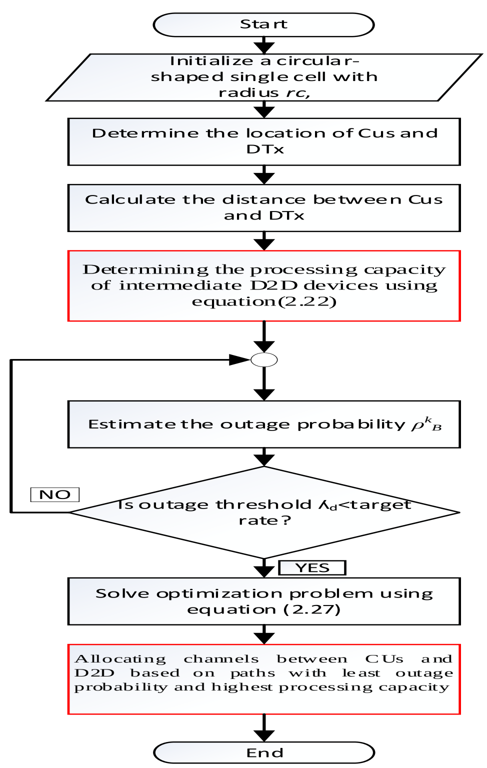


Figure 2: The Flowchart for iCA-PIL

Table 1: Simulation Parameters

Parameter	**Value**
Simulator The simulator v	MATLAB 2018
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

Table 1. Shows a list of complete network parameters used for this simulation.

IV. RESULTS AND DISCUSSION

This section discusses the various results obtained through simulations in MATLAB and are presented and discussed from 1-3.

4.1. Maximum ET per Active D2DC versus Number of D2DC

Figure 3 is a graph of max ET per active D2DC versus the number of D2DC devices. During simulation, the numbers of cellular users J or K are 6 and 4. It can generally be observed that the difference between the number of cellular users and D2DC affects the network max Effective Throughput (ET) per active D2DC. A large difference between *J* and *T* (number of D2D cluster devices) results in higher selection gains and hence a higher max ET per active D2DC. Equation (5) was used in calculating the ET of the network. In CA-PIL, When *J*=4, 6 and *T* D2DC lays between 2 and 4, it can be observed that the ET decreases. This is due to small difference between *J* and *T* which led to low selection gain. However, as the T D2DC increases above 4, the difference between J and T increases which led to higher selection gain that translates to higher ET. Also, in iCA-PIL, it can be observed that a large difference between *J* and *T* results in higher selection gains and hence a higher max ET per active D2DC. But the performance of iCA-PIL in terms of max ET per active D2DC is better than CA-PIL because of the additional processing capacity constraint which made it possible for correct, efficient and effective path to be discovered and used during resource allocation. This will reduce routing load on mobile node and improve the network lifetime in underlay cellular network.

Hence, the performance of iCA-PIL during communication is practically more efficient.

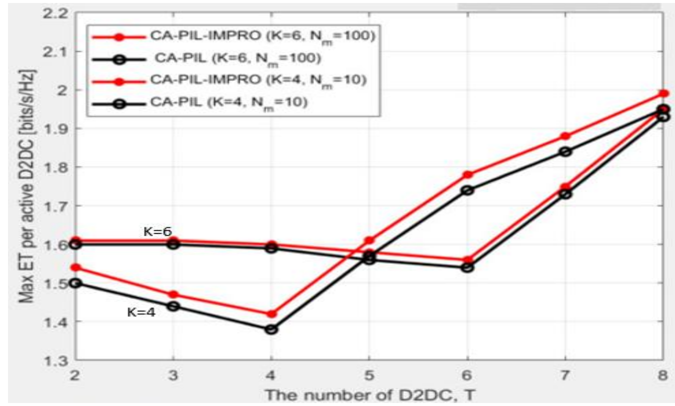
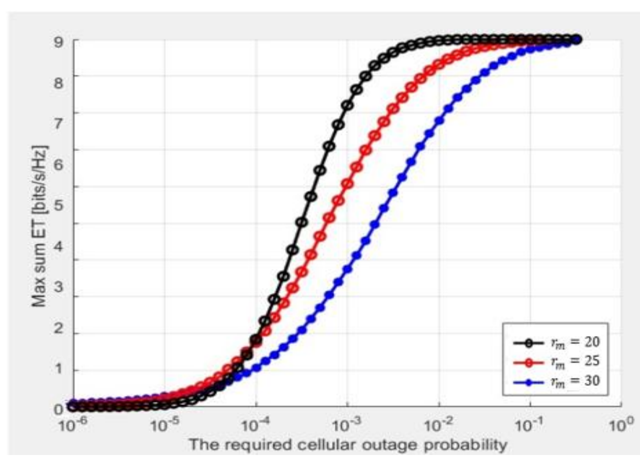


Figure 3: Plot of max ET Per Active D2DC versus Number of D2DC

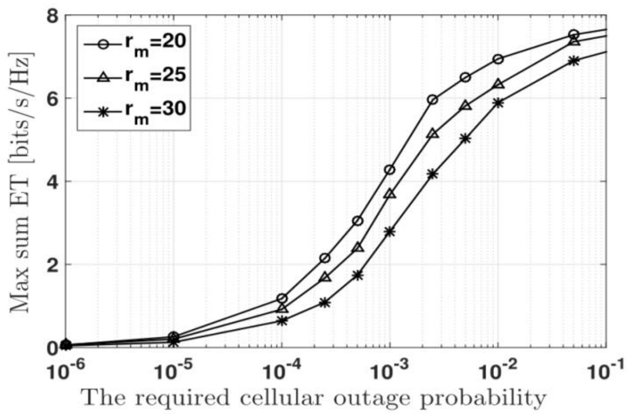
4.2. Maximum Sum ET versus Cellular Outage Probability

Figure 4 shows the relationship between the maximum sum Effective Throughput (max sum ET) and the required cellular outage probability for both CA-PIL and iCA-PIL schemes. From the graph, it can be observed that as the outage probability of the network increases, there is a corresponding increase in the max sum ET. This is because, an increase in outage probability will results in increase in the transmit power of D2D transmitters ($R_{D_{Tx}}$). The increase in $R_{D_{Tx}}$ entails a higher probability of successful transmission of data to D2D receivers ($R_{D_{Rx}}$). It is also observed from the graph that, the smaller the cluster size, the higher the maximum sum effective throughput.

The number of D2D receivers per cluster (N_t or N_m) considered during simulation was 100. The ET was calculated using equation (5).



iCA-PIL



CA-PIL

Figure 4: Plot of Max Sum ET versus Required Cellular Outage Probability.

V. CONCLUSION

In this dissertation report, an improved Channel Allocation using Partial Information of device Location (iCA-PIL) that improve the underlay cellular networks energy efficiency, maximum ET per active D2DC, maximum ET and data rate is presented. This scheme takes into consideration the processing capacity of D2DC devices and their corresponding outage probability to improve the energy efficiency and effective throughput of cellular networks. The iCA-PIL scheme mitigates the possibility of having inefficient routing paths used for data dissemination. A cellular link outage threshold and D2D link outage threshold of 5dBm each was used during simulation.

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