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Enhanced D2D Communication Model in 5G Networks

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Abstract: Device-to-Device (D2D) communication model employs device-centric wireless connectivity. D2D maintains reliability of links, enhances spectrum utilization and energy consumption. Hence, it is expected to play an important role in 5th Generation (5G) mobile networks. However, D2D incurs challenges in resources management, and device discovery. This paper improves D2D performance by redefining and developing its clustering and communication models. Also, a context adaptive device proximity discovery technique is presented. The proposed proximity model uses several factors for accurate device measurements, this includes Received Signal Strength Indicator (RSSI), network density and distance between participating devices. An intensive evaluation and comparison study was conducted. Results have confirmed that proposed D2D achieved an improved performance comparing to similar models by reducing overall end-to-end (E2E) delay and improving packet delivery ratio (PDR) in the network. During simulation scenarios, average PDR achieved was 93.2% and average E2E delay experienced was 2.9 ms.

Keywords:5G; D2D; RSSI; Clustering; PDR, E2E.

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1. INTRODUCTION

Considering the rapid increase of connected devices, traffic volumes, and application requirements, current 4G technologies is not able to fulfill user expectations. 5G mobile network is intended to combine root solutions of current limitations and improve the communication architecture to support more users, provide higher data rates, increased capacity and lower control traffic and latency [1]. 5G networks are expected to be much more dynamic and densely deployed than previous mobile networks [2].In the same concern, 5G networks will support wide spread of applications and network deployment such as Internet of Things (IoT), which is the promising paradigm to combine several technologies and communications solutions [3]. In order to improve performance of current cellular technologies, Third Generation Partnership Project (3GPP) provides an enhanced Long-Term Evolution (LTE) radio interface known as LTE-Advanced (LTE-A). This includes a set of technologies including carrier aggregation, massive Multiple-Input Multiple-Output (MIMO), as well as D2D communication [4].

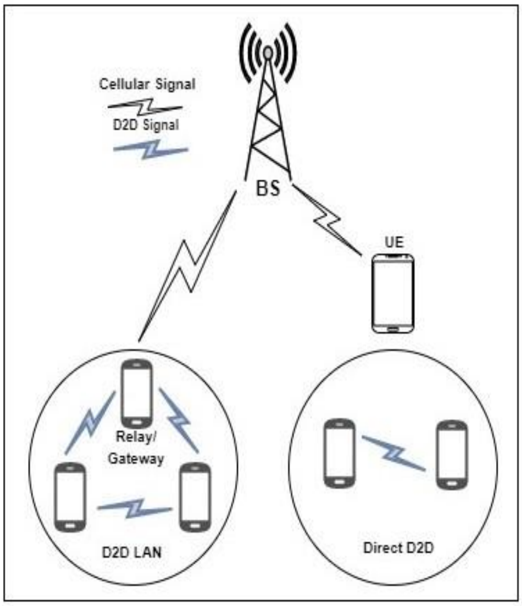

Figure 1. D2D Communication Model [5]

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D2D is considered as a promising technology allowing 5G achieving higher performance supporting increasing user demands [6]. As shown in figure 1, D2D communication model provides a useful infrastructure based on cellular or adhoc links. It supports two fundamental structure types; the first one does not involve reference Base Station (BS) or Evolved Node B (eNB), known as (Direct D2D), the second structure described as network-based D2D where base station exists to support and control all data transmissions and signaling between devices [7]. In addition, D2D nodes will form clusters, in which traffic propagates between nodes directly within the same cluster, or forwarded outside the cluster to the BS via CH nodes. Using its multiple communication paradigm, D2D communication covers an increased number of nodes and provides an improved network coverage area. D2D node discovery and clustering techniques are important procedures to be considered to efficiently find and link potential D2D peers. In (LTE-A) node discovery procedure is under full control of (eNB). However, power consumption, power control and interference management are aspects addressed in D2D technology as described in LTE-A enhancements [4]. This work investigates D2D nodes' proximity and discovery limitations. The proposed approach utilizes a set of factors related to nodes capability and network topology for D2D nodes discovery and clustering.

2. LITERATURE REVIEW

5G network integrates several technologies forming a heterogeneous network (HetNet) [2]. This includes a set of radio access technologies, a hierarchy of cells described as macro, pico, and femto cells, large antenna arrays at BS known as massive MIMO, cognitive radio network (CRN), and D2D communication model. The last component supports HetNets and allows the implementation of new performance revealing services and applications. The D2D is exposed to provide a set of advantages such as improving spectral utilization and data rates, as well as enhancing energy consumption and system capacity significantly. However, D2D technology experience some challenges, such as resource management and allocation, nodes discovery and clustering, handover management, and nodes' clustering efficiency [7, 8].

Interference management is an important issue to be considered in D2D. In [9]an intensive survey of recent interference management approaches in D2D communication is presented. Where, a qualitative comparison was provided to classify these approaches and define their suitability within 5G environments. Proximity discovery is an important step for setting up D2D links and pairing neighboring devices. In [10] a signaling algorithm is presented to interchange channel details and proximity messages between participating devices and BS. The focus was to provide accurate estimation of D2D links. In addition, an integrated D2D discovery technique was presented in [11], a signaling algorithm was used to exchange discovery messages between mobile devices. Also, cellular resources were shared to initiate D2D links between potential participating devices. In the other hand, nodes clustering is an important aspect to be considered in D2D to reduce signaling traffic and energy consumption in 5G networks. Hence, efficient nodes clustering is required especially in high nodes density environments. This mainly depends on nodes' approximation accuracy and cluster head (CH) selection. Generally, number of cluster members depends on set of factors such as CH capability, coverage range, traffic intensity, and nodes' distribution and location. Hence, CH node selection affects cluster size, and overall Quality of Service (QoS) provided to cluster members [11].

A number of algorithms for CH and cluster members' selection were presented in [12, 13, 14]. In [12], a clustering algorithm for in-band D2D communication is presented, which increases system efficiency and throughput. In the same concern, [13] investigates using D2D communications for improving data throughput and ensuring energy efficiency of cellular networks. The node with highest channel quality is chosen as CH, and is responsible for receiving and forwarding traffic between cluster members and BS. Hence, load balance was achieved and network overhead was significantly reduced. A D2D model based mobile cloud infrastructure was described in [15]. In which, cluster members were divided into three types; Primary Cluster Head (PCH), Secondary Cluster Head (SCH) and standard mobile devices. Evaluation results of this model have indicated its efficiency related to energy consumption and improved throughput.

In the same concern, [16] presented an advanced model for clustering mobile nodes known as Improved clustering for Virtual MIMO-based topology construction (ICV-MIMO), which aims to define cluster transmission modes and ranges adaptively. Reported evaluation results of this model confirmed its efficiency in reducing energy consumption and improving overall cluster lifetime. In [17] a comparison of D2D clustering approaches was presented to identify effective methods required to improve network resources utilization. Hence, a novel throughput optimization model for out-of-band D2D clusters was described. In addition, [18] investigates the use of out-of-band D2D communications, and provides D2D clustering techniques, where CH selection is based on channel quality between CH and BS.

Resource allocation of D2D communication in 5G networks was investigated in [19, 20]. The focuse of [19] was to increase the number of D2D links taking into cosnideration power consumption and transmision rate requirements. In [20] a new approach for improving the capacity and throughput of D2D links was described by optimizing channel resources and power control.

Accordingly, several research works have indicated the importance of using D2D technology in 5G networks, as a major solution of network overhead, latency and for improved link reliability. However, the efficiency of D2D communication is an ongoing concern to be addressed to exploit its advantages in 5G networks. Several clustering algorithms was investigated throughout previous research. Most of these algorithms focused towards spectrum utilization as a major method solving the clustering problem. However, for more efficient clustering, different QoS and context related parameters should be considered in CH selection and cluster members' association. This includes cumulative throughput, number of neighboring nodes, signal strength, coverage range, and available energy. This work focuses on improving the performance of D2D communication by presenting a new approach for efficient nodes discovery and clustering.

3. PROPOSED MODEL:

The proposed nodes proximity discovery model comprises two main phases. The first phase is responsible for building communication cluster. The second phase defines data communication and forwarding model.

A. *Phase 1: Nodes Clustering*

RSSI values between mobile nodes and BS are continuously measured. Mobile nodes achieving strongest and highest RSSI values are selected as CHs and linked directly to the BS. CH should confirm with a threshold value of signal strength with BS. Afterwards, clusters are defined, each cluster will consist of one CH and K neighbor members, where K is predefined and presents the maximum number of cluster members. The number of clusters ***n*** is based on network density D and K value, this can be computed as follows:

$$n = \frac{D}{K} \tag{1}$$

For each cluster, a center position is defined based on CH current position. However, in order to accommodate continuous changes of members' positions, cluster center needs to be updated based on the cluster members updated location. This can be computed as follows:

$$p_{c_i} = \frac{1}{|C_i|} \sum_{j \in C_i} L \tag{2}$$

Where:

- p_{c_i} is the mean value of cluster members' position.
- L is the location information of cluster members.
- $|\mathrm{C_i}|$ is the actual number of members in cluster $\mathrm{C_i}$

The CH node will broadcast the HELLO message and will wait for REPLY message from neighboring nodes. If the CH received replies from more than K nodes, then CH sends JOIN messages to only K neighbors achieving minimum distance to CH, after acknowledgments are received, these nodes will be attached to CH and become cluster members. Accordingly, three node types will exist within the network topology; Cluster Member (CM), Non-Cluster Member (NCM), and Cluster Head (CH). NCM are nodes not receiving JOIN messages. The use of distance and K neighbors' constraints results in optimizing the number of cluster members, which allows CH increase data aggregation and reduce transmission energy. This will also reduce the overall clustering delay.

B. *Phase 2: Nodes Communication*

This phase defines how data is forwarded and methods of communication between mobile devices. Three communication methods will take place within D2D network architecture. This includes no-hop, single-hop, and multi-hop communication methods. The introduction of these three communication methods will improve the overall performance of D2D links including throughput and delay.

Single-hope communication will exist within the same cluster, in which CMs will send and receive data to each other directly or via CH according to available channel, time slots and buffer space. Multi-hop communication allows nodes located at different clusters to communicate, in which CH will forward CMs' data between clusters via the Base Station (BS).BS is responsible to forward data to corresponding CH. BS organizes all requests coming from all CHs within specific queue capacity. If the queue has available space, packets are processed; otherwise, its dropped. NCMs are considered as independent nodes able to communicate directly with each other using no-hop communication. NCMs can also communicate with BS or CH directly to access other CMs using single or multi-hop communication methods.

The overall operational function of both phases is described using the pseudocode presented in figure 2.

```
Algorithm1: proposed D2D proximity discovery model
M = set of mobile nodes.
N = set of neighbor nodes.
C = set of cluster members.
B = set of non-cluster members.
$n$ = Number of clusters.
While($m \in M$ & $j \le n$)
    //Phase 1:Nodes Clustering.
    Measure RSSI between m and BS.
    CH: m with highest RSSI.
    $j = j + 1$
    CH broadcast Hello messages.
    N = Set of neighbor nodes sending reply messages.
```

```
12: While($m \in N$)
//Distance threshold between n and CH.
13: Measure distance between m and CH.
14:   If Distance <= Distance_Th
// Sort according to distance
15:   $i = i + 1$
16:   If i<= K
17:       $m \in C$
//add node to CH cluster.
18:Else $m \in B$
19:   End If
20:   End while
21: End while
22://Phase 2: Nodes Communication
23:   If $m1 \,\&\, m2 \in B$
// m1 is sender and m2 is receiver.
24:   m1 send packet to m2 directly
//no-hop communication.
25: Establish D2D connection between
no-hop nodes.
26:   Else m1 send IP packet to CH
27:If ID of m2 within cluster
// Single-hop communication.
28: Send packet -> m2
29: Establish D2D connection between
single-hop nodes.
30: Else CH will forward packet to
nearest BS
//Multi-hop communication.
31: Find CH for m2.
32: Send packet -> Destination CH.
33: Destination CH will then Forward
packet to m2.
34: End If
35:   End IF
36: End Algorithm
```

Figure 2. Proposed D2D Functional Approach

Where:

- Lines 1 to 21 represents nodes clustering phase. Lines 6 to 11 are responsible for selecting CH based on RSSI and distance.
- Lines from 12 to 21 are used for creating cluster, selecting and associating cluster members.
- Lines 22 to 36 represents nodes communication and forwarding phase. Communication models are divided into three major categories; no-hop, one-hop and multi-hop.
- Lines 23 and 25 represents no-hop communication where direct packet delivery is performed between neighboring peers.
- Lines 26 to 29 represents single-hop communication where both sending and receiving nodes are within the same cluster. The CH will be the communication hop responsible for packet delivery.
- The last communication approach is multi-hop where the BS will be involved to deliver packets between nodes located in different clusters, this approach is represented in lines 30 to 36.

4. EVALUATION AND RESULTS ANALYSIS

A comprehensive simulation scenario was built using MATLAB implementing 5G network environment. Using this scenario, the performance of proposed proximity discovery model was evaluated in terms of Packet Delivery Ratio (PDR) and End-to-End (E2E)delay. Table 1 describes major simulation parameters.

TABLE I. SIMULATION SETTINGS

Parameters	Value
Network Grid Size	(600 x 600) m
Number of Clusters	6
Head range (cluster size)	100
Number of mobile devices	700,900,1100,1300
Initial Energy	0.5
Number of Rounds	1000
Queue size of CH	50
Queue size of BS	100
Probability of sending packet to a queue	0.5
Probability of packet leaving a queue	0.5
Iterations	50, 100, 150, 200, 250

PDR refers to the ratio of successfully received packets at destinations to the total number of packets sent by the sender. PDR is computed as shown in equation below [21]:

$$PDR = \left(\frac{No\ of\ Packets\ Received}{\text{Total Pack Sent} - \text{Pending Pack}}\right)100\% \quad (3)$$

E2E delay is the overall time required for of packet to travel from source to destination. This includes several delay components such as; transmission, propagation, and processing delays. E2E delay is computed as follows [21]:

$$E2E = \sum_{m=1}^{n} \frac{(Recvied\ Time - Sent\ Time)}{Number\ of\ Transmission} \quad (4)$$

PDR indicates transmission and routing efficiency. Figure 3 reports results of PDR performance, where the ratio of received packets to the number of devices used during the simulation is illustrated. Although of increased node density the proposed model performed high PDR values, in which an average of 93.2% was achieved. This is due to efficient data communication methods being implemented by proposed approach. In addition, adapting cluster size and number of clusters to network topology and density has maintained acceptable node to node connectivity and reduced number of link failures. Hence, network lifetime is increased achieving higher data rates while experiencing less delay. This explains the improved delay performance as illustrated in figure 4.

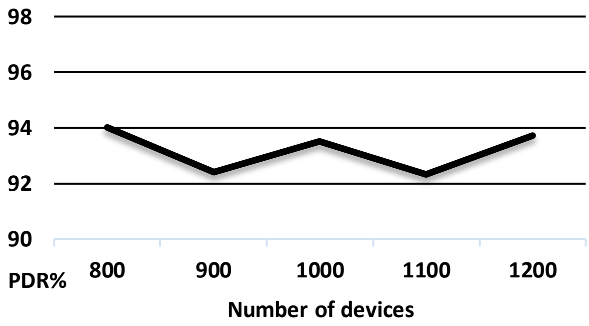

Figure 3. PDR performance of proposed model

Figure (4) shows the average E2E delay, where the values were fluctuating based on the number of mobile devices. However, in overall it was clear that proposed model performs acceptable E2E delay achieving an average of 2.9ms during the simulation study.

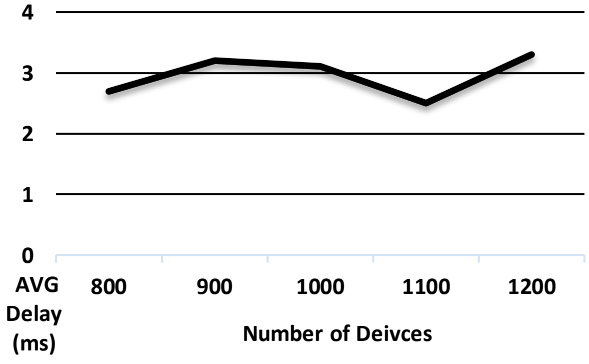

Figure 4. Average E2E delay performance of proposed approach

Furthermore, proposed approach was compared with mobile clustering technique described by [16], known as ICV-MIMO as being described earlier in section 2. During this performance comparison study, large network grid size (1000*1000) and high node density (1500) were used. The comparison was based on PDR and E2E delay as illustrated in figures 5 and 6 respectively. Proposed approach achieved an average PDR value of 92.9%, comparing to 91.5% achieved by ICV-MIMO. In terms of E2E delay, proposed approach experienced 3.5 ms, however ICV-MIMO experienced 4.9 ms. Also, it is worth mentioning that results achieved in this work are considered comparable to results reported by similar studies such as [18] and [22]. Accordingly, this confirms the validity of proposed approach and its capability to achieve improved performance during different simulated environmental challenges.

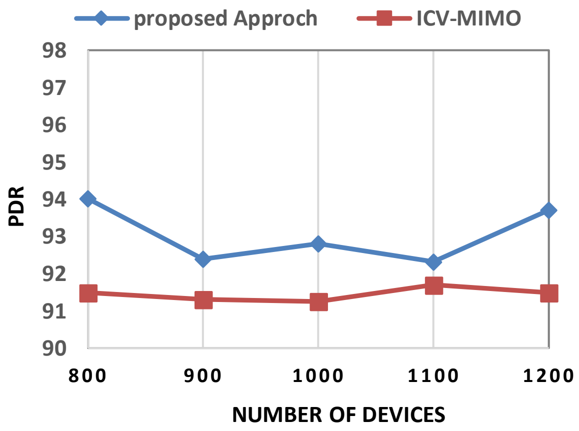

Figure 5. PDR Results Comparison

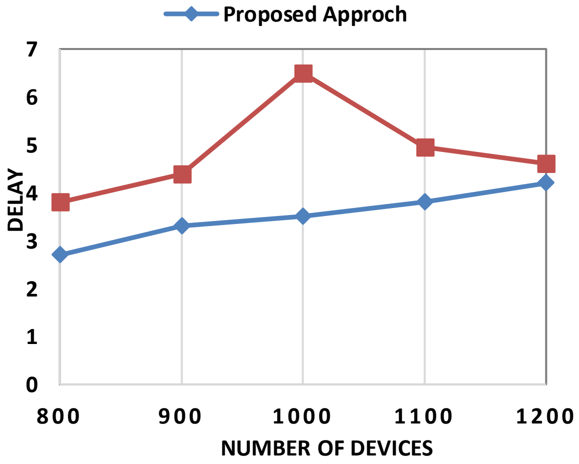

Figure 6. E2E Delay Comparison

5. CONCLUSION

This paper described a new proximity discovery model in order to improve efficiency and reliability of D2D communication in 5G network. For accurate nodes approximation and increased links reliability, the proposed model has utilized several factors described as RSSI and distance of participating nodes. This has assisted in defining optimal CH and efficiently clusters nodes or attach them directly to BS. The conducted evaluation and comparison study has confirmed the advanced performance achieved by proposed D2Dmodel, in which average PDR achieved was 93.2% and average E2E delay experienced was 2.9 ms.

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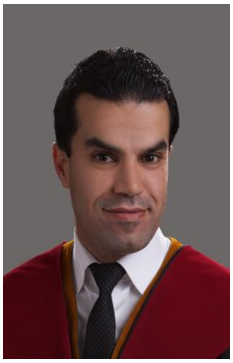

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