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DEVICE-TO-DEVICE COMMUNICATIONS WITH 5G NETWORKS

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Abstract: In this paper, we endorse an opportunistic cooperation approach for D2D transmission with the aid of exploiting the caching capability on the users to govern the interference amongst D2D hyperlinks. We recall overlay inband D2D, divide the D2D users into clusters, and assign specific frequency bands to cooperative and non-cooperative D2D hyperlinks. To provide the excessive possibility for cooperative transmission, we introduce a caching policy. To maximize the network throughput, we collectively optimize the cluster length and bandwidth allocation, in which the closed-shape expression of the bandwidth allocation element is received.

Keywords: Caching, D2D, Cooperative transmission, Interference, High Throughput

I. INTRODUCTION

During the past decade, the volume of mobile data traffic has increased at a rapid pace and quantitative studies predict that the exponential growth will continue in the future as illustrated in Figure 1.1. The growth is mainly due to emerging popular multimedia applications that are supported by new types of devices such as smartphones and tablets. Moreover, multiple devices may be used by the same user to connect to the Internet through the existing cellular infrastructure, which contributes to increased data traffic. Consequently, the total mobile data traffic generated is predicted to have a 1000-fold increase by the year 2020. This is extremely demanding in terms of network resources and link capacity. Besides the issue of large data volume in the upcoming decade, user experience is also an important challenge.

Current networks may offer good quality-of-service (QoS) in isolated areas, but they cannot meet the extreme capacity demands of future wireless systems in areas where they have to handle situations where users are located in close proximity to one another, such as shopping malls, festivals, stadiums, and even office buildings. Users want to be connected anytime, anywhere. Increasing capacity and connectivity will translate into higher energy consumption and costs, which in turn are not economical or sustainable from an operational perspective. During the years, mobile broadband technologies have evolved. Long-term evolution (LTE) and LTE-Advanced systems, which have embodied the fourth generation (4G) networks, have reached a certain level of maturity. Now, we are on the verge of a transition into a state of

fully connected society where high capacity is needed, but incremental changes in the current systems and technologies are not enough to make this transition fundamental changes are needed to handle future non-homogeneous networks as well as new trends in user behavior and applications such as high quality video streaming and augmented reality. Therefore, discussions of a new standard have taken place in academia and industry in order to envision the needs and requirements of, and possible use cases 5G is not yet clear, but it needs to take into account a wider range of use cases and characteristics. Therefore, stringent key performance indicators (KPIs) and tight requirements have been proposed in order to handle higher mobile data volumes, reduce latency, and increase the number of connected devices, while at the same time increasing energy efficiency (EE) and reducing costs. 5G networks are supposed to support the existing and evolving technologies and simultaneously integrate new solutions which have been proposed to meet the new requirements. In order to increase network capacity, one option is to improve the efficiency of available radio resources; another option is to increase resources such as the amount of available spectrum, the number of antennas and the number of base stations (BSs). However, adding radio resources is not necessarily cost and energy efficient, and it may sometimes take a long time for them to be put into practice. There are many new concepts, design criteria, and scenarios that have been proposed for 5G; some of them, if implemented, will bring fundamental changes at the architectural and node level.

One example of such proposed technologies is device-to-device (D2D) communications which will change the nature of conventional network design. In early generations of mobile systems, the network-centric design was introduced, based on the notion of cell, uplink, and downlink communications. At that time, the application of mobile networks was mainly for voice communication and there was an implicit assumption that users are not in close proximity to one another. However, this assumption is not tenable anymore as the main current trends are content (file) sharing and interest sharing (e.g., online-gaming and social networks, where users in close proximity happen to interact more). Hence, it is important to consider proximity awareness as a design parameter. To this end, one of the broad visions of 5G is its emphasis on device-centric solutions and the need for smarter devices. D2D communication appears to be an enabling technology for this vision, which allows users in close proximity to communicate directly with each other, bypassing the base station (BS).

II. RELATED WORK

To take the advantage of the storage capacity at smart phones, cache-enabled D2D communications have been proposed recently, which can offload the content delivery traffic and hence boost the network throughput significantly [18, 19]. Since only the users in proximity communicate to each other, the distance between a user and the undesired transmitters can be close and hence the interference in D2D networks is strong, which needs to be carefully controlled. In an early work of studying cache-enabled D2D communications, the

D2D users are divided into clusters. Then, the intra-cluster interference among D2D links is managed by using time division multiple access (TDMA), while the inter-cluster interference between D2D links is simply treated as noise [18]. In [19], only the D2D link from one of the four adjacent clusters is allowed to be active at the same time-frequency resource block, in order to avoid strong inter-cluster interference among adjacent clusters. In [20], interference alignment was employed to mitigate the interference among D2D links, but only three D2D links were coordinated within each cluster, and the interference among clusters was again treated as noise. In [21–23], cooperative relay techniques were proposed to mitigate the interference between cellular and D2D links, which however can not manage the interference among the D2D links.

III. PROPOSED WORK

Consider a cellular network, where M single-antenna users are uniformly located in a square hotspot within a macro cell, where the area is with the side length of D_c as shown in Fig. 1. Each user is willing to store N files in its local cache and can act as a helper to share files. When a helper conveys a file in local cache via the D2D link to a DR requesting the file, the helper becomes a DT. The BS is aware of the cached files at each user and coordinates the D2D communications. We consider a static content catalog including N files that the users may request. To simplify the analysis, each file is assumed with the same size as in [15–19]. Although in practice the files are with unequal sizes, each file can be divided into chunks of equal size [16], so the same

analysis can still be applied. The N_f files are indexed in a descending order of popularity, e.g., the 1st file is the most popular file.

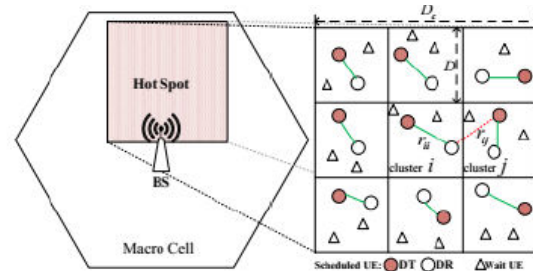


Fig. 1. Cluster division model, “UE” means user equipment.

B. Communication Protocol

D2D links can be established among users in proximity owing to the limited transmit power at each user equipment (UE) and the possible strong interference among UEs. A widely used communication protocol for D2D communications is that two UEs can communicate if their distance is smaller than a given distance [18, 29]. To control the strong interference and make the analysis tractable, the square hotspot area is divided into B smaller square areas called clusters as in [19], where the side length of each cluster is $D = D_c = pB$. For mathematical simplicity, we assume that the number of users per cluster is $K = M = B$ and each user is assumed to transmit with the same power P as in [19]. For the non-cooperative users, only those within the same cluster can establish D2D links in order to control interference. For the cooperative users, the users in different clusters are allowed to establish D2D links to avoid interference and exploit multiplexing gain by joint transmission.

Opportunistic cooperation strategy: In this segment, we first introduce a caching policy to provide high opportunity for cache-enabled cooperative

D2D transmission. Then, we propose an opportunistic cooperativetransmission policy. Finally, we optimize two key parameters in the strategy to maximize the network throughput.

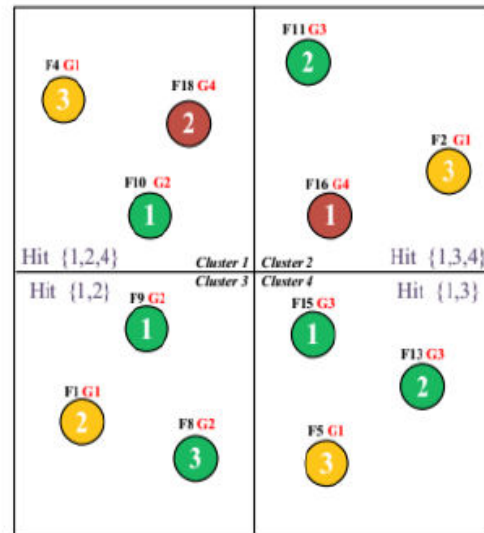
A. Caching Policy To maximize the probability that a user can fetch filesthrough D2D links, the users within a cluster should cachedifferent files. To maximize the probability of cooperativetransmission among DTs in different clusters, the files cachedat the users of each cluster should be the same. This suggeststhat the caching policy needs to balance the diversity of contentwith the redundancy of the replicas of popular contents.

B. Opportunistic Cooperative Transmission Policy According to whether a user can find the requested file inthe hotspot area, we can classify the users into two types.

D2D users: If the file requested by a user is cached atany UE in the cluster it belongs to (and hence also cachedin UEs in other clusters according to the above-mentionedcaching policy), then the user can directly obtain the filewith D2D communication, either without or with cooperation.Such a user is referred to as a D2D user. Besides, if the filerequested by a user is in its local cache, it can retrieve thefile immediately with zero delay, but we ignore this case foranalysis simplicity as in [19].

Cellular users: If the file requested by a user is not cachedin the UEs within the hotspot area, the user fetches the filefrom the BS and becomes a regular cellular user. The numberof cellular users is denoted as

Nb. For easy understanding, we introduce the strategy with thehelp of an example.



F9 G2 Requests the 9th file in the 2nd file group
 ● Coop user ● N-Coop user ● Cellular user
 ③ The 3rd user cached with the 3rd file group.
 Hit {1,2,4} The cluster hit the file group {1,2,4}

Fig. 2. Illustration of the opportunistic cooperation strategy. Catalog size $N_f = 20$, $B = 4$ clusters in the hotspot, $K = 3$ users in each cluster and each user caches $N = 5$ files.

1) Cooperative D2D Users: If there exists at least one user in a cluster requesting the files in G_k , then we say that the cluster hits the k th file group. In Fig. 2, the users in the first cluster respectively request the files in G_1 , G_2 and G_4 , and hence the first cluster hits the {1; 2; 4}th file groups. If every cluster hits the same file group G_k , the k th user in each cluster who caches the file group G_k can act as a DT, and all DTs in these clusters cooperatively transmit files to the DRs requesting the files in G_k . Those DRs are referred to as cooperative D2D users (Coop users for short), whose number is denoted as N_c .

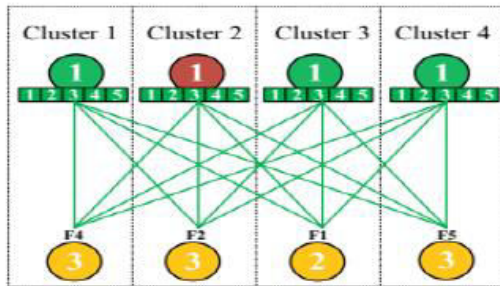


Fig. 3. Illustration for cooperative transmission from multiple DTs to DRs.

In Fig. 2, every cluster hits the 1st file group. Hence, the 1st users in all the four clusters who cache the files in G1 can act as DTs to cooperatively transmit files with indices {4; 2; 1; 5} respectively to the 3rd user in cluster 1, the 3rd user in cluster 2, the 2nd user in cluster 3, and the 3rd user in cluster 4, as shown in Fig. 3

C. Optimization of Cluster Size and Bandwidth Allocation In this subsection, we jointly optimize the bandwidth allocation factor η and cluster size K to maximize the average network throughput under a constraint that the average user data rate is larger than a given value, μ (Mbps). Because we assume overlay D2D communications, only D2D users are considered in the network throughput.

IV. CONCLUSION

In this paper, we proposed an opportunistic cooperation strategy for cache-enabled D2D communications. We at the same time optimized the cluster size and the bandwidth allotted to Coop and N-Coop customers to maximise the community throughput with minimum consumer information price constraint.

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