# Downlink Resource Sharing and Multi-tier Caching Selection Maximized Multicast Video Delivery Capacity in 5G Ultra-Dense Networks

Thanh-Minh Phan[1], Nguyen-Son Vo[2](✉), Minh-Phung Bui[3],
Quang-Nhat Tran[3], Hien M. Nguyen[4], and Antonino Masaracchia[5]

[1] Ho Chi Minh City University of Transport, Ho Chi Minh City 700000, Vietnam
ptminh@hcmutrans.edu.vn
[2] Institute of Fundamental and Applied Sciences, Duy Tan University,
Ho Chi Minh City 700000, Vietnam
vonguyenson@duytan.edu.vn
[3] Van Lang University, Ho Chi Minh City 700000, Vietnam
{buiminhphung,tranquangnhat}@vanlanguni.edu.vn
[4] Faculty of Electrical-Electronic Engineering, Duy Tan University,
Da Nang 550000, Vietnam
nguyenminhhien2501@gmail.com
[5] Queen's University Belfast, Belfast BT7 1NN, UK
a.masaracchiag@qub.ac.uk

**Abstract.** In this paper, we propose a downlink resource sharing and multi-tier caching selection (DRS-MCS) solution for video streaming applications and services (VASs) in 5G ultra-dense networks (UDNs). The DRS-MCS allows mobile users (MUs) to experience the VASs by multicasting from three-tier caching placements, i.e., macro base station (MBS), femtocell base stations (FBSs), and mobile devices. To do so, the MUs are categorized into three types including 1) sharing users (SUs) that own downlink resources being shared for device-to-device (D2D) communications, 2) caching helpers (CHs) that cache the requested videos for multicasting over D2D communications, and 3) requesting users (RUs) that request the videos. The CHs and the RUs are grouped into different clusters, each cluster has a number of CHs and RUs in close vicinity for D2D multicast communications. We then formulate the DRS-MCS optimization problem. By solving the problem, the DRS-MCS solution can select not only the best pairs of SUs and CHs for D2D multicast communications but also the best caching placements for multicasting in each cluster, so as to maximize the total video capacity delivered to the RUs. Simulation results are shown to demonstrate the benefits of the proposed DRS-MCS solution compared to other conventional multicasting schemes.

**Keywords:** 5G ultra-dense networks · Caching and clustering · D2D multicast communications · Resource sharing · Video applications and services

N.-S. Vo and V.-P. Hoang (Eds.): INISCOM 2020, LNICST 334, pp. 19–31, 2020.
https://doi.org/10.1007/978-3-030-63083-6_2

## 1 Introduction

By 2022, it anticipates that together with the rapid increase of mobile users (MUs), the video applications and services (VASs) will bloom and use up about 79% of the mobile data traffic [1]. It is certain in VASs that there are a number of MUs in close vicinity of each other that have the same interest of video contents. In this context, by exploiting the benefits of common interest-sharing nature of dense MUs and broadcast nature of wireless medium, multicasting techniques play an important role in emerging 5G networks since they can provide the system with a high energy- and spectrum-efficiency solution and a high video delivery capacity [2,3].

Most of the multicasting techniques have been studied to apply to device-to-device (D2D) communications [4,5] with the assistance of the MUs that have cached the videos for streaming, namely caching helpers (CHs), and have available downlink resources for sharing, namely sharing users (SUs) [6–12]. The results achieved include tractable model for analysis and optimization design of coverage probability and system capacity [6], reduction in streaming cost at better fairness [7], minimum video delivery delay [8–10], and maximum energy efficiency [11] and sum effective throughput [12]. Other multicasting techniques have further exploited both physical communications features and social attributes of MUs to gain higher system performance [13–20]. However, these studies cannot provide a flexible multicasting strategy to serve the requesting users (RUs) that request the videos by fully utilizing the three-tier caching placements, i.e., macro base station (MBS), femtocell base stations (FBSs), and CHs over D2D communications, in 5G ultra-dense networks (UDNs).

Few of multicasting techniques have been proposed to serve the RUs flexibly by the MBS over conventional cellular transmission and by the CHs over D2D communications with downlink resources shared by the SUs [21,22]. In particular, the authors in [21] have designed a downlink resource sharing and caching helper selection solution to maximize the multicast video delivery in dense D2D 5G networks. The proposed solution has been insightfully studied by considering the social attributes between the CHs and the RUs as well as the constraint on the skewed fairness of RUs, so as to further satisfy the RUs [22]. The existing problem of the works in [21,22] is that they do not exploit the caching placement at the FBSs to fully provide the RUs with three-tier caching selection for the highest system capacity.

In this paper, we utilize the three-tier caching placements at the MBS, the FBSs, and the CHs as well as the downlink resources available at the SUs to propose a downlink resource sharing and multi-tier caching selection (DRS-MCS) solution for VASs in 5G UDNs. To do so, we formulate the DRS-MCS optimization problem for finding the best pairs of the CHs and the SUs in order to multicast the requested videos from the CHs to the RUs over D2D communications that reuse the downlink resources of the SUs. In addition, the DRS-MCS is able to select the best caching placements, i.e., the MBS, the FBSs, or the CHs, to serve the RUs in different clusters at maximum system capacity. The DRS-MCS optimization problem also considers a constraint on the target signal

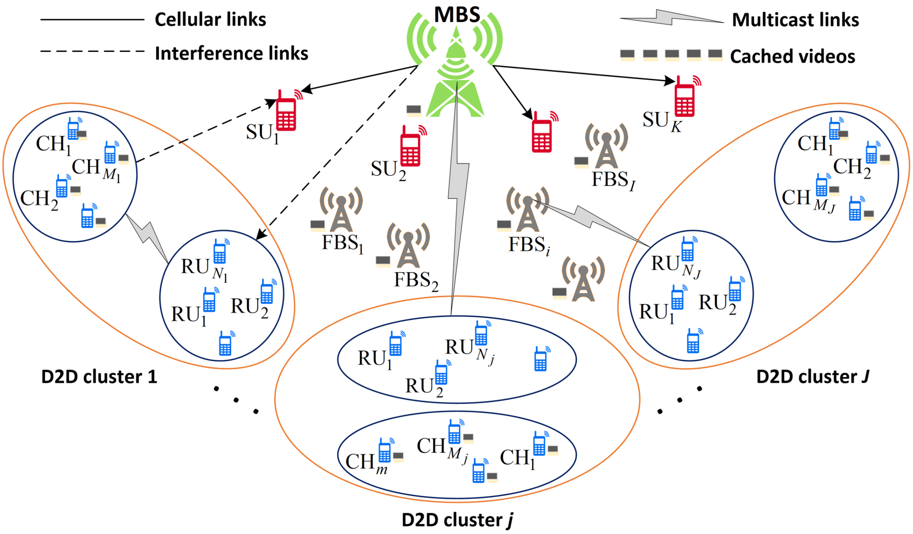

**Fig. 1.** Multicast Video Streaming in 5G UDNs with DRS-MCS.

to interference plus noise ratio (SINR) of the SUs to guarantee their quality of service (QoS) which is certainly degraded due to the transmissions of the CHs when reusing the downlink resources of the SUs. Simulation results are shown with insightful analysis and discussion to demonstrate the benefits of the proposed DRS-MCS solution compared to other schemes such as conventionally multicasted by the MBS and by both the MBS and the FBSs but without downlink resource sharing.

The rest of this paper is organized as follows. We introduce the system model of multicast video streaming in 5G UDNs with DRS-MCS and describe how it works in Sect. 2. In Sect. 3, we derive the system formulations that enable us to propose the DRS-MCS optimization problem and solution in Sect. 4. The performance evaluation is presented in Sect. 5. Finally, we conclude the paper in Sect. 6.

## 2 System Model

In this paper, we consider a system of multicast video streaming in 5G UDNs with DRS-MCS as shown in Fig. 1. The system consists of one MBS, $I$ FBSs, $K$ SUs, and $J$ clusters. The cluster $j$, $j = 1, 2, ..., J$, has $M_j$ CHs that have cached the requested videos and $N_j$ RUs that request the videos. The system provides three ways to flexibly multicast the videos to the RUs that are 1) multicast from the MBS over conventional cellular transmissions, 2) multicast from the FBSs by applying the channel splitting and F-ALOHA schemes that are able to guarantee no interference [23], and 3) multicast over D2D communications by reusing the downlink resources shared by the SUs. At the appropriate time, if there are a number of RUs requesting a particular video, the MBS deploys the DRS-MCS strategy including three steps presented as follows:

- Step 1 - Clustering: To deploy the DRS-MCS strategy, it is necessary to group the CHs and the RUs that are in close vicinity for D2D communications into $J$ clusters. We apply the D2D clustering technique proposed in [24], in order to expand the coverage area of each cluster so that there are $M_j$ CHs and $N_j$ RUs in the cluster $j$.
- Step 2 - Formulating and solving the DRS-MCS optimization problem: The MBS further collects the system parameters such as the number of SUs and channel information from the MBS, FBSs, and CHs to the RUs and from the MBS and CHs to the SUs. These parameters enable the MBS to formulate the DRS-MCS optimization problem and solve it for the optimal downlink resource sharing index $v_j^{m,k}$. If $v_j^{m,k}$ evaluates to 1 (or 0), the SU $k$ does (or does not) share its downlink resource for D2D multicast communications from the CH $m$ to $N_j$ RUs in the cluster $j$, $m = 1, 2, ...M_j$. For the purpose of limiting the interference impact caused by the transmissions of CHs on the SUs, i.e., guaranteeing the QoS of the SUs, the DRS-MCS optimization problem considers the constraints such that an SU can share its downlink resource with up to only one CH in the whole system and the target SINR of the SUs is greater than or equal to a given threshold.
- Step 3 - Multicasting: After solving the DRS-MCS optimization problem, the MBS decides which one, i.e., itself, an FBS, or a CH, multicasts the video to all the RUs in the cluster $j$. In other words, the RUs in the cluster $j$ are served by the MBS, the FBS, or the CH, depending on from which the channel quality is better so that the total multicast video capacity delivered to all RUs in the system is maximized.

## 3 System Formulations

### 3.1 Wireless Channel

In this paper, the wireless channel gains are modeled as $G_j^{\mathsf{x},\mathsf{y}} = h_j^{\mathsf{x},\mathsf{y}} g_j^{\mathsf{x},\mathsf{y}}$ [25,26], here $\mathsf{x} \in \{0, i, m\}$, $\mathsf{y} \in \{n, k\}$, $i = 1, 2, ..., I$, $h_j^{\mathsf{x},\mathsf{y}}$ is the exponential power fading coefficient with unit mean, i.e., $\sim$exp(1), and $g_j^{\mathsf{x},\mathsf{y}} = \|d_j^{\mathsf{x},\mathsf{y}}\|^{-\eta}$ is the standard power law path loss function with path loss exponent $\eta$, $d_j^{\mathsf{x},\mathsf{y}}$ is the distances from the MBS ($\mathsf{x}$=0), the FBS $i$ ($\mathsf{x}$=$i$), and the CH $m$ ($\mathsf{x}$=$m$) to the RU $n$ ($\mathsf{y}$=$n$) and the SU $k$ ($\mathsf{y}$=$k$).

### 3.2 Capacity at RUs

To obtain the video capacity delivered to the RUs, it is required to compute the SINR from the CHs to the RUs and the signal to noise ratio (SNR) from the MBS and the FBSs to the RUs which are respectively presented in the sequel.

In the cluster $j$, if the CH $m$ is selected to multicast the video to the RU $n$ by reusing the downlink resource shared by the SU $k$, the SINR from the CH $m$ to the RU $n$, which is affected by the interference generated from the conventional cellular transmission of the MBS to the SU $k$, is given by

$$\gamma_j^{m,k,n} = \frac{v_j^{m,k} P_j^m G_j^{m,n}}{N_0 + P_0^k G_j^{0,n}}, \tag{1}$$

where $P_j^m$ and $P_0^k$ are the transmission powers of the CH $m$ in the cluster $j$ and of the MBS (indicated by 0) to the SU $k$; $G_j^{m,n}$ and $G_j^{0,n}$ are the channel gains from the CH $m$ and the MBS to the RU $n$ in the cluster $j$; and $N_0$ is the power of additive white Gaussian noise.

In case there is not any SUs sharing the downlink resources with the CHs, the FBSs are considered multicasting the video to the RUs. The SNR from the FBS $i$ to the RU $n$ in the cluster $j$ is given by

$$\gamma_j^{i,n} = \frac{P_j^{i,n} G_j^{i,n}}{N_0}, \tag{2}$$

where $P_j^{i,n}$ is the transmission power of the FBS $i$ to the RU $n$ and $G_j^{i,n}$ is the channel gain from the FBS $i$ to the RU $n$ in the cluster $j$.

In addition, we further compute the SNR from the MBS to the RU $n$ in the cluster $j$ which is expressed as

$$\gamma_j^{0,n} = \frac{P_0^j G_j^{0,n}}{N_0}, \tag{3}$$

where $P_0^j$ is the transmission power of the MBS to the RUs in the cluster $j$.

So far, the capacity at the RU $n$ in the cluster $j$ delivered from the CH $m$, the FBS $i$, and the MBS is respectively given as below

$$C_j^{m,k,n} = W \log_2(1 + \gamma_j^{m,k,n}), \tag{4}$$

$$C_j^{i,n} = W \log_2(1 + \gamma_j^{i,n}), \tag{5}$$

and

$$C_j^{0,n} = W \log_2(1 + \gamma_j^{0,n}), \tag{6}$$

where $W$ is the system bandwidth.

Finally, the total system capacity delivered from the MBS, FBSs, and CHs to the RUs in all clusters is expressed as

$$\begin{aligned} C = \sum_{j=1}^{J} \max \Big\{ \sum_{n=1}^{N_j} C_j^{0,n}, \max \{ \sum_{n=1}^{N_j} C_j^{i,n}, i = 1, 2, ..., I \}, \\ \sum_{k=1}^{K} \sum_{m=1}^{M_j} \sum_{n=1}^{N_j} C_j^{m,k,n} \Big\}, \end{aligned} \tag{7}$$

In Eq. (7), $C$ is so-called the objective function in the DRS-MCS optimization problem.

**Algorithm 1.** EBSA for DRS-MCS optimization problem

```
Input: Initial system parameters given in Table 1
Output: $\mathcal{V}^*$, $C^*$
Generating $J$ search space matrices
    $\mathcal{V}_1 = \{V^1_{M_1 \times K}, V^2_{M_1 \times K}, ..., V^{2^{M_1 \times K}}_{M_1 \times K}\}$
    $\mathcal{V}_2 = \{V^1_{M_2 \times K}, V^2_{M_2 \times K}, ..., V^{2^{M_2 \times K}}_{M_2 \times K}\}$
    ...
    $\mathcal{V}_J = \{V^1_{M_J \times K}, V^2_{M_J \times K}, ..., V^{2^{M_J \times K}}_{M_J \times K}\}$
$C^* \leftarrow 0$
for each matrix $v_1$ in $\mathcal{V}_1$, $v_1 = 1, 2, ..., 2^{M_1 \times K}$ do
    for each matrix $v_2$ in $\mathcal{V}_2$, $v_2 = 1, 2, ..., 2^{M_2 \times K}$ do
        . . .
        for each matrix $v_J$ in $\mathcal{V}_J$, $v_J = 1, 2, ..., 2^{M_J \times K}$ do
            if $J$ matrices satisfy (9b), (9c), and (9d) then
                Computing $C$ in (7)
                if $C > C^*$ then
                    $C^* \leftarrow C$
                    $\mathcal{V}^* \leftarrow \{V^{v_1}_{M_1 \times K}, V^{v_2}_{M_2 \times K}, ..., V^{v_J}_{M_J \times K}\}$
                end if
            end if
        end for
        . . .
    end for
end for
```

### 3.3 SINR at SUs

In the DRS-MCS strategy, the SUs have to share the downlink resources with the CHs for D2D multicast communications. This in turn makes the QoS of the SUs degraded due to the interference from the transmissions of the CHs when reusing the downlink resources. To limit the interference impact on the SUs for a high QoS guarantee, it is necessary to compute the SINR at the SU $k$ which is given by

$$\gamma^k = \frac{P_0^k G_0^k}{N_0 + v_j^{m,k} P_j^m G_j^{m,k}}, \tag{8}$$

where $G_0^k$ and $G_j^{m,k}$ are the channel gains from the MBS and the CH $m$ in the cluster $j$ to the SU $k$.

## 4 DRS-MCS Optimization Problem and Solution

The DRS-MCS optimization problem aims at maximizing the objective function $C$ (7). We further take into account the constraints on $v_j^{m,k}$ so that an SU can share its downlink resource with up to only one CH in the whole system (9b) and there is up to only one SU sharing its downlink resource with one CH in a cluster (9c). In addition, the target SINR $\gamma_0$ is considered to guarantee the QoS of the SUs (9d). The DRS-MCS optimization problem is formulated as below

$$\max_{v_j^{m,k}} C \tag{9a}$$

$$\text{s.t.} \ \textstyle\sum_{k=1}^{K} \sum_{m=1}^{M_j} v_j^{m,k} \leq 1, j = 1, 2, ..., J, \tag{9b}$$

$$\textstyle\sum_{j=1}^{J} \sum_{m=1}^{M_j} v_j^{m,k} \leq 1, k = 1, 2, ..., K, \tag{9c}$$

$$v_j^{m,k} P_j^m G_j^{m,k} \leq \frac{P_0^k G_0^k}{\gamma_0} - N_0, k = 1, 2, ..., K, \tag{9d}$$

$$j = 1, 2, ..., J, m = 1, 2, ..., M_j.$$

where the constraint (9d) is derived from Eq. (8) by letting $\gamma^k \geq \gamma_0$.

The DRS-MCS optimization problem is solved by using exhaustive binary searching algorithm (EBSA) [27] presented in **Algorithm** 1. To solve the DRS-MCS optimization problem, we separate $v_j^{m,k}$ into $J$ variables associated with $J$ clusters, the variable $j$, i.e., $V_j = V_{M_j \times K}$, is an $M_j \times K$ matrix. So, finding $v_j^{m,k} = 1$ (or 0) is equivalent to finding the element at the row $m$ and the column $k$ of the matrix $V_j$ evaluates to 1 (or 0). The variable $V_j$ has its own search space of $\mathcal{V}_j = \{V^1_{M_j \times K}, V^2_{M_j \times K}, ..., V^{v_j}_{M_j \times K}, ..., V^{2^{M_j \times K}}_{M_j \times K}\}$, $v_j = 1, 2, ..., 2^{M_j \times K}$.

In **Algorithm** 1, line 1 generates $J$ search spaces of $J$ variables. The search space $j$ has $2^{M_j \times K}$ matrices. Then, the output maximum value $C^*$ is initially set at 0 in line 2. In lines 3–6, each permutation of $J$ matrices created by selecting a matrix in each search space is considered checking if it satisfies the constraints (9b), (9c), and (9d) or not (line 7). If satisfied, the objective function $C$ is computed (line 8) to obtain a higher value $C^*$ and find the corresponding result $\mathcal{V}^*$ (lines 9–11). The EBSA terminates when it completes the computation of all permutations for finding the maximum value $C^*$ and the optimal result $\mathcal{V}^*$. It is noted that the EBSA introduces a high memory and time complexity of $\mathcal{O}(2^{K \times \sum_{j=1}^{J} M_j})$. However, we apply the EBSA to solving the DRS-MCS optimization problem thanks to its simple implementation for the exact optimal results. Finding other proper algorithms that achieve exact or approximated optimal results at lower memory and time complexity is beyond the scope of the paper.

## 5 Performance Evaluation

In this paper, the system parameters used to deploy the DRS-MCS strategy for multicast video streaming in 5G UDNs are listed in Table 1. The distances between the MBS and the SUs/RUs, the FBSs and the RUs, the CHs and the SUs, and the CHs and the RUs are randomly uniform distributed in the ranges of [100, 1,000] m, [50, 200] m, [50, 100] m, and [1, 50] m, respectively. To evaluate the performance of the proposed DRS-MCS solution, we compare it to other schemes including average capacity (AVE), minimum capacity (MIN), without

**Table 1.** Parameters Setting

| Symbols | Specifications |
|---|---|
| $I$ | 5 FBSs |
| $J$ | 5 Clusters |
| $K$ | 5 SUs |
| $\{M_j\}$ | $\{2, 4, 6, 8, 10\}$ CHs |
| $\{N_j\}$ | $\{5, 10, 15, 20, 25\}$ RUs |
| $W$ | 5 MHz |
| $P_0^j$, $P_0^k$ | Fixed to 5W |
| $P_j^{i,n}$ | Fixed to 0.1W |
| $P_j^m$ | Randomly uniform distributed in the range of [0.001, 0.01]W |
| $N_0$ | $10^{-13}$W |
| $\eta$ | 4 (path loss exponent) |
| $\gamma_0$ | 5 dB |

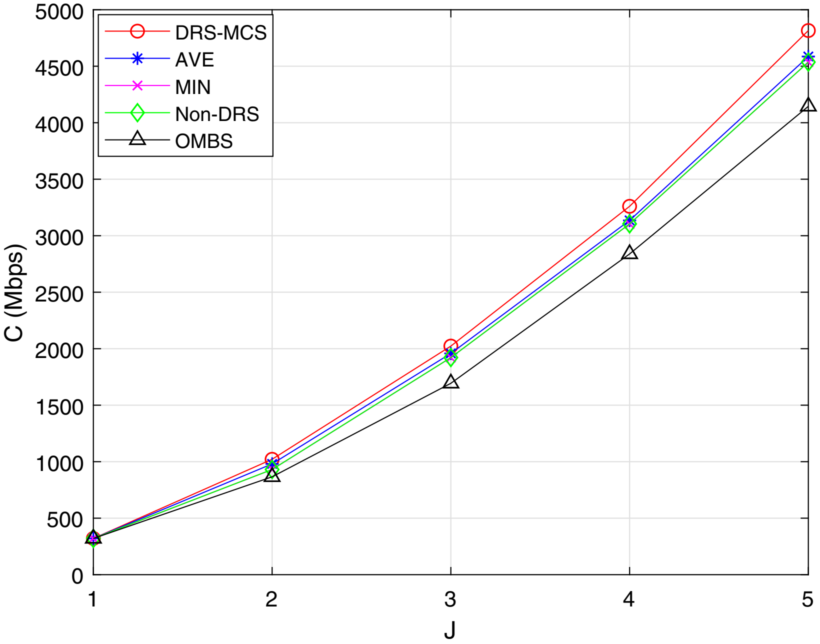

**Fig. 2.** System performance versus the number of clusters $J$.

downlink resource sharing (Non-DRS), and only MBS (OMBS). In AVE and MIN, we compute the average capacity and the minimum capacity of all the permutations in $J$ search spaces that satisfy the constraints (9b), (9c), and (9d),

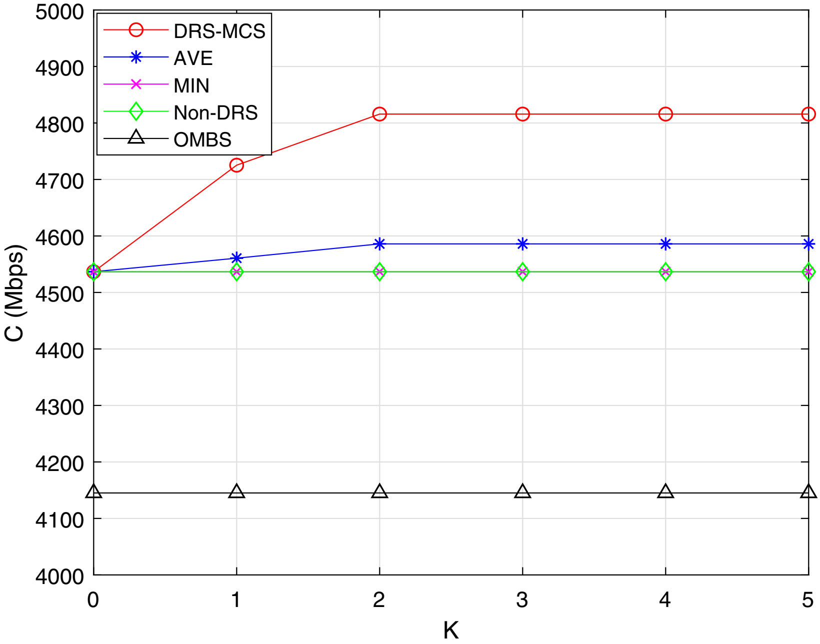

**Fig. 3.** System performance versus the number of SUs $K$.

instead of computing the maximum capacity as given in **Algorithm** 1. In Non-DRS, we do not consider sharing the downlink resources of the SUs. And in OMBS, the RUs are traditionally served by the MBS.

We evaluate the system performance of DRS-MCS, AVE, MIN, Non-DRS, and OMBS versus the number of clusters $(J)$ as shown in Fig. 2. If $J = 1$, the performance of all schemes are the same since the best caching placement selected to serve the RUs is the MBS. Increasing $J$ yields the higher number of RUs served by MBS, FBSs, and D2D multicast communications, and thus providing the RUs with higher system capacity. In comparison, the DRS-MCS outperforms the others thanks to more caching placement selection opportunities. The AVE, MIN and Non-DRS gain higher performance than the OMBS since they can further exploit the FBSs to serve the RUs. It is noted that the MIN and Non-DRS provide the RUs with the same performance since the minimum capacity of DRS-MCS is equivalent to the context of Non-DRS. The OMBS serves the RUs the worst system capacity due to no FBSs nor DRS assisted.

The system performance of DRS-MCS, AVE, MIN, Non-DRS, and OMBS versus the number of SUs $(K)$ is illustrated in Fig. 3. We can observe that if there is no SU $(K = 0)$ to share the downlink resources, the performance of DRS-MCS, AVE, MIN, Non-DRS are the same, but it is higher than that of the OMBS thanks to the assistance of FBSs. Increasing $K$ provides more downlink resource sharing opportunities to increase the performance of DRS-MCS

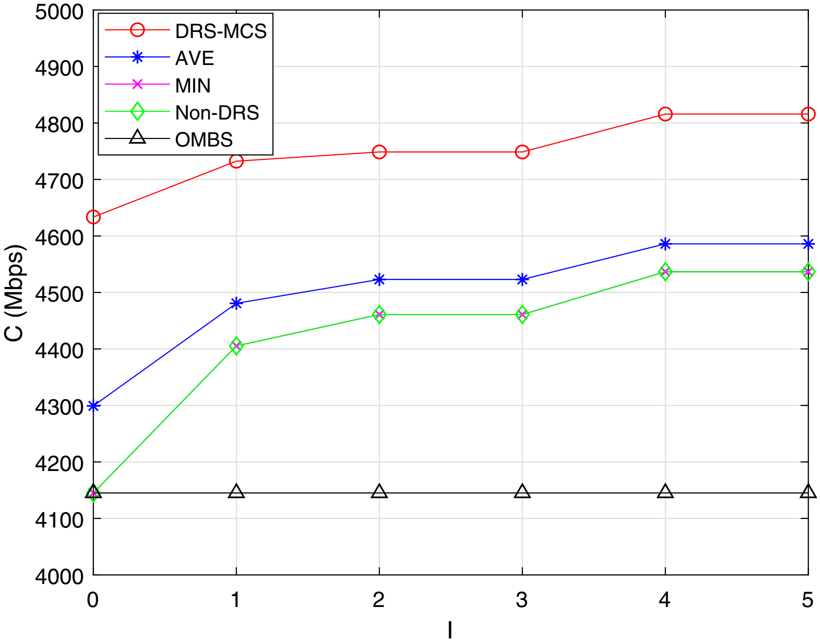

**Fig. 4.** System performance versus the number of FBSs $I$.

and AVE. Meanwhile, the performance of MIN and Non-DRS is the same and keeps unchanged with respect to $K$. Interestingly, the system performance gets saturated when $K$ is high enough, i.e., $K = 3$. This finding helps the system designers consider selecting a proper number of SUs for high system capacity at reasonable computation cost of EBSA.

Figure 4 plots the system performance versus the number of FBSs ($I$). The results show that if there is no FBS ($I = 0$), the MIN and Non-DRS obviously become the OMBS due to no FBSs nor DRS assisted. The performance of DRS-MCS, AVE, MIN, and Non-DRS increases in accordance with the increase of $I$, but getting saturated if $I$ is high enough ($I = 4$) or the new FBSs added are not better in terms of providing higher system capacity than the existing ones. In comparison, the DRS-MCS always outperforms the other AVE, MIN, Non-DRS, and OMBS schemes. In addition, similar to selecting the number of SUs, implementing DRS-MCS strategy must carefully consider selecting a proper number of FBSs to gain high system capacity at reasonable cost of computational resource and system architecture modification.

In Fig. 5, we further investigate the effect of the target SINR ($\gamma_0$) of SUs on the performance of DRS-MCS, AVE, MIN, Non-DRS, and OMBS. It is certain that increasing $\gamma_0$ to guarantee the QoS of SUs reduces the downlink resource sharing opportunities. As a result, the performance of DRS-MCS and AVE is reduced to that of MIN and Non-DRS when $\gamma_0 = 25\,\text{dB}$. It is important to

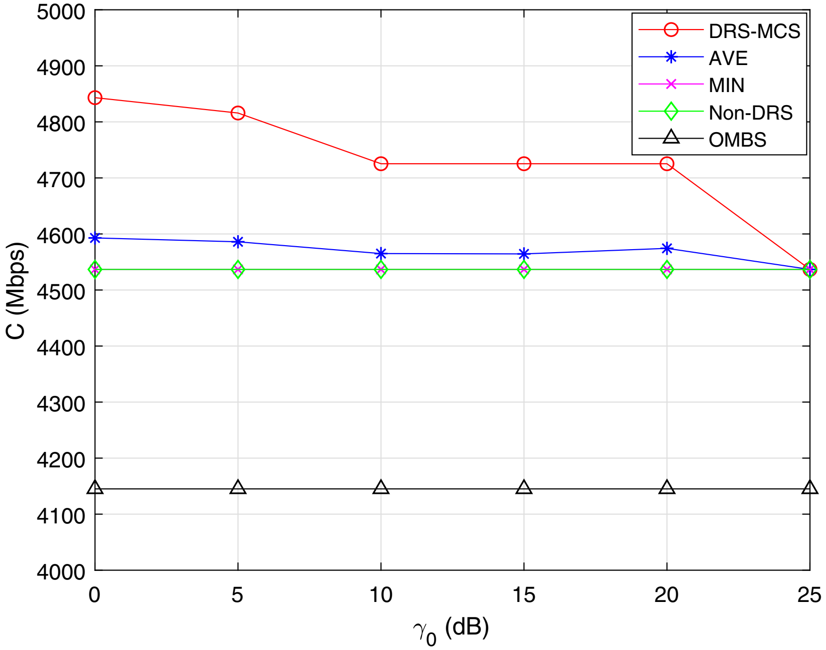

**Fig. 5.** System performance versus the number of FBSs $\gamma_0$.

observe that the proper value of $\gamma_0$ should be carefully selected so that the system capacity is high enough while guaranteeing the SUs a high QoS, $\gamma_0 = 5\,\text{dB}$ for example. Depending on the QoS demands of SUs, different values of $\gamma_0$ can be selected to make the DRS-MCS gain different system performances that are always higher than the system performances of other schemes.

## 6 Conclusion

In this paper, we have proposed the DRS-MCS solution for video streaming applications and services in 5G UDNs. The proposed DRS-MCS not only allows the RUs to receive the videos flexibly multicasted from the three-tier caching placements, i.e., MBS, FBSs, and CHs, but also enables to pair the SUs that have available downlink resources with the CHs that cache the videos, for D2D multicast communications by reusing the shared downlink resources. The objective of the DRS-MCS solution is to serve the RUs the highest system capacity while guaranteeing the QoS of the SUs by limiting the interference transmitted by the CHs that reuse the downlink resources of the SUs. Simulation results are insightfully analyzed to demonstrate the benefits of the proposed DRS-MCS solution compared to the other schemes. In addition, useful suggestions for system design and modification are provided to achieve the most effective DRS-MCS solution.

**Acknowledgement.** This research is funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number 102.04-2018.308.

## References

1. Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," in 2017–2022 White Paper, February 2019. https://www.cisco.com
2. Lecompte, D., Gabin, F.: Evolved multimedia broadcast/multicast service (eMBMS) in LTE-advanced: overview and Rel-11 enhancements. IEEE Commun. Mag. **50**(11), 68–74 (2012)
3. Araniti, G., Condoluci, M., Scopelliti, P., Molinaro, A., Iera, A.: Multicasting over emerging 5G networks: challenges and perspectives. IEEE Netw. **31**(2), 80–89 (2017)
4. Thanh, T.L., Hoang, T.M.: Cooperative spectrum-sharing with two-way AF relaying in the presence of direct communications. EAI Endorsed Trans. Ind. Netw. Intell. Syst. **5**(14), 1–9 (2018)
5. Nguyen, T.H., Nguyen, D.Q., Nguyen, V.D.: Quality of service provisioning for D2D users in heterogeneous networks. EAI Endorsed Trans. Ind. Netw. Intell. Syst. **6**(21), 1–7 (2019)
6. Lin, X., Ratasuk, R., Ghosh, A., Andrews, J.G.: Modeling, analysis, and optimization of multicast device-to-device transmissions. IEEE Trans. Wirel. Commun. **13**(8), 4346–4359 (2014)
7. Zulhasnine, M., Huang, C., Srinivasan, A.: Exploiting cluster multicast for P2P streaming application in cellular system. In: Proceedings of IEEE Wireless Communications and Networking Conference, Shanghai, China, April 2013, pp. 1–6 (2013)
8. Peng, B., Peng, T., Liu, Z., Yang, Y., Hu, C.: Cluster-based multicast transmission for device-to-device (D2D) communication. In: Proceedings of IEEE 78th Vehicular Technology Conference, Las Vegas, NV, September 2013, pp. 1–5 (2013)
9. Militano, L., Condoluci, M., Araniti, G., Molinaro, A., Iera, A., Muntean, G.-M.: Single frequency-based device-to-device-enhanced video delivery for evolved multimedia broadcast and multicast services. IEEE Trans. Broadcast. **61**(2), 263–278 (2015)
10. Zhu, Y., Qin, X., Zhang, P.: An efficient multicast clustering scheme for D2D assisted offloading in cellular networks. In: Proceedings of IEEE/CIC International Conference on Communications in China, Beijing, China, August 2018, pp. 1–5 (2018)
11. Hmila, M., Fernandez-Veiga, M., Rodriguez-Perez, M.: Distributed resource allocation approach for device-to-device multicast communications. In: Proceedings of International Conference on Wireless and Mobile Computing, Networking and Communications, Limassol, Cyprus, October 2018, pp. 1–8 (2018)
12. Kim, J.-H., Joung, J., Lee, J.W.: Resource allocation for multiple device-to-device cluster multicast communications underlay cellular networks. IEEE Commun. Lett. **22**(2), 412–415 (2018)
13. Cao, Y., Jiang, T., Chen, X., Zhang, J.: Social-aware video multicast based on device-to-device communications. IEEE Trans. Mob. Comput. **15**(6), 1528–1539 (2016)
14. Zhao, P., Feng, L., Yu, P., Li, W., Qiu, X.: A social-aware resource allocation for 5G device-to-device multicast communication. IEEE Access **5**, 15717–15730 (2017)

15. Moghaddam, S.S., Ghasemi, M.: Efficient clustering for multicast device-to-device communications. In: Proceedings of International Conference on Computer and Communication Engineering, Kuala Lumpur, Malaysia, September 2018, pp. 1–6 (2018)
16. Yang, L., Wu, D., Cai, Y.: A distributed social-aware clustering approach in D2D multicast communications. In: Proceedings of International Wireless Communications and Mobile Computing Conference, Limassol, Cyprus, pp. 1–6 (2018)
17. Wu, Y., Wu, D., Yang, L., Shi, X., Ao, L., Fu, Q.: Matching-coalition based cluster formation for D2D multicast content sharing. IEEE Access **7**, 73913–73928 (2019)
18. Yang, L., Wu, D., Xu, S., Zhang, G., Cai, Y.: Social-energy-aware user clustering for content sharing based on D2D multicast communications. IEEE Access **6**, 36092–36104 (2018)
19. Wu, Y., Wu, D., Yang, L., Xu, S.: Incentive-based cluster formation for D2D multicast content sharing. In: Proceedings of Asia-Pacific Conference on Communications, Ningbo, China, November 2018, pp. 1–6 (2018)
20. Feng, L., Zhao, P., Zhou, F., Yin, M., Yu, P., Li, W., Qiu, X.: Resource allocation for 5G D2D multicast content sharing in social-aware cellular networks. IEEE Commun. Mag. **56**(3), 112–118 (2018)
21. Phan, T.-M., Vo, N.-S., Bui, M.-P., Dang, X.-K., Ha, D.-B.: Downlink resource sharing and caching helper selection control maximized multicast video delivery capacity in dense D2D 5G networks. J. Sci. Technol. **18**(4.2), 12–20 (2020)
22. Vo, N.-S., Phan, T.-M., Bui, M.-P., Dang, X.-K., Viet, N.T., Yin, C.: Social-aware spectrum sharing and caching helper selection strategy optimized multicast video streaming in dense D2D 5G networks. IEEE Syst. J. 1–12 (2020)
23. Cheung, W., Quek, T., Kountouris, M.: Throughput optimization, spectrum allocation, and access control in two-tier femtocell networks. IEEE J. Sel. Areas Commun. **30**(3), 561–574 (2012)
24. Gyawali, S., Xu, S., Ye, F., Hu, R.Q., Qian, Y.: A D2D based clustering scheme for public safety communications. In: Proceedings of IEEE 87th Vehicular Technology Conference, Porto, Portugal, pp. 1–5 (2018)
25. Vo, N.-S., Duong, T.Q., Tuan, H.D., Kortun, A.: Optimal video streaming in dense 5G networks with D2D communications. IEEE Access **6**, 209–223 (2017)
26. Bhardwaj, A., Agnihotri, S.: Energy- and spectral-efficiency trade-off for D2D-multicasts in underlay cellular networks. IEEE Wirel. Commun. Lett. **7**(4), 546–549 (2018)
27. Vo, N.-S., Duong, T.Q., Guizani, M., Kortun, A.: 5G optimized caching and downlink resource sharing for smart cities. IEEE Access **6**, 31457–31468 (2018)