

Quality Adaptation in Network Edge for Layered Video in D2D Communication Networks

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Abstract

We have entered in 5th generation (5G) of cellular communication to meet the ever increasing user demand for bandwidth-intensive applications like high quality video on the move. However, due to the unique nature of video streaming, networking engineers need to think about the application specific solution along with the improvement of the network throughput to full-fill the modern-day demands. In this paper, we propose video quality adaptation in the network edge that covers the D2D communication as well as the cellular communication for the H.264/SVC encoded layered video. According to our mechanism, user put request for a video. The Base-Station/Small-cell-Base-Station (BS/SBS) searches the requested contents in the cache of other UEs and pairs the content requesting UEs to the content providing UEs and assign them the network resources for the communication. The remaining requests are fulfilled via cellular transmission. The proposed optimization problem is combinatorial in nature and is NP hard. We propose a heuristic algorithm to solve the problem. Our performance evaluation reveals significance of the proposed mechanism.

1. Introduction

With the proliferation of high specification smart mobile devices, High quality video on the move is becoming one of the basic commodities of life [1]. Despite exhausting the frequency domain in the 4th generation of cellular communication and massive MIMO and frequency reuse in the shape of small cells in the 5th generation (5G) of cellular networks finding it difficult to cope with the increasing demand of high quality video for a huge user base in the shape of Internet-of-Things (IoT). To further enhance the frequency reusability, to deal with the increasing user demands, Device-to-Device (D2D) communication is considered a mandatory part of the 5G networks. The research community is thinking to improve the structure of the future Internet [2]–[5], [8]. However, for video streaming, selecting video quality according to the network conditions is very important for high quality and continuous video. Moreover, video streaming is having unique characteristics, in shape of delay and throughput requirements than other applications. Therefore, networking engineers need to think about the application specific solution for video streaming to full-fill the modern-day demands like covered in [6]. In this paper, we propose video quality adaptation and network resource allocation in the network edge that covers the Device-to-Device (D2D) communication as well as the cellular communication for the H.264/SVC encoded layered video. In our mechanism, user put request for a video. The Base-Station/Small-cell-Base-Station (BS/SBS) searches the requested contents in the cache of other UEs and pairs the content requesting UEs to the content providing UEs and assign them the network

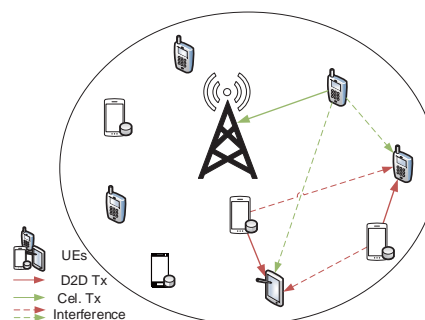


Figure 1: System Architecture

resources for the communication. The proposed optimization problem is combinatorial in nature and is NP hard. In order to solve the formulated problem, we propose a heuristic algorithm. Our performance evaluation reveals the significance of the proposed mechanism.

2. System Architecture

Our proposed network architecture is a typical 5G cellular system consisted of a BS/SBS and cellular UEs. There are total N User Equipments (UEs) in the system consisted of Cellular User Equipments (CUEs) and D2D User Equipments (DUEs). The DUE are consisted of cache equipped and non-equipped devices as shown in figure 1. The cache equipped DUEs can cache the videos and provide it to other UEs if they request those videos.

D2D transmissions take place at the uplink period. A D2D pair receives interference from all other D2D transmitters as well as cellular users (CUs) transmitters operating on the same channel. The BS/SBS manages the spectrum and distributes it among all the transmitters. Since all the transmissions in the systems are wireless which weakens with increase in the distance due to relay fading. In our

mechanism, we are also considering the channels are relay fading and the same channel can be reused if the noise is less than a threshold.

In our system, when a UE needs a video segment, first it searches its own cache to find it, if fails to find then the UE sends request to BS/SBS for a segment of the H.264/SVC encoded layered video along with the deadline for getting this segment. The BS searches for the video in the cache of the DUEs inside the transmission range of the requesting UE, if found, then the DUEs are informed by the BS and then network resources are assigned to them for the transmission. The communication scenario is given in figure 2.

3. Communication Model

Total Interference on a DUE receiver is calculated as follow:

$$I_i = \sum_{i' \neq i, i' \in N} P_i h_{i',j} d_{i',j}^{-\alpha} + P_c h_c d_c^{-\alpha}, \quad (1)$$

where P_i is the transmit power of the transmitting DUE i , $h_{i,j}$ is the gain of DUEs i and j , $d_{i,j}$ is the distance between the DUEs and α is the exponent of path-loss. $\sum_{i' \neq i, i' \in N} P_i h_{i',j} d_{i',j}^{-\alpha}$ is the total interference from all other DUEs transmitters on the same channel, $P_c h_c d_c^{-\alpha}$ is the interference of CUE on the D2D receiver.

Signal-to-Interference-Noise-Ratio (SINR), for the DUE pair represented by $(\gamma_{i,j})$, is calculated as follow:

$$\gamma_{i,j} = \frac{P_i h_{i,j} d_{i,j}^{-\alpha}}{I_i + \sigma^2}, \quad (2)$$

where σ^2 is the Gaussian noise. The transmission rate (Shannon capacity) of DUEs, represented by $r_{i,j}$, is calculated as follow:

$$r_{i,j} = W \log_2(1 + \gamma_{i,j}), \quad (3)$$

where, W is the channel bandwidth.

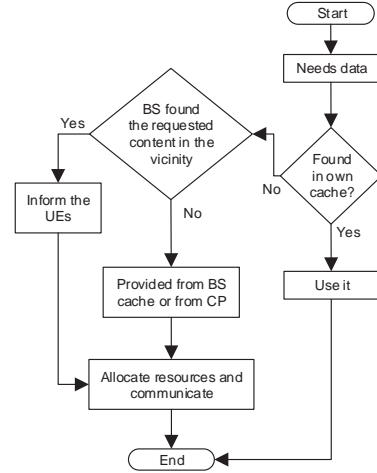
Our utility function is as follow:

$$U_i^s = m_i^s(q_i) - \mu v_i^s(q_i) \quad (4)$$

where $m_i^s(q_i)$ is the mean quality of the video segments and s is the segment number, $\mu v_i^s(q_i)$ is the variation between the segments of the video.

4. Problem Formulation

We aim to improve the user Quality of Experience (QoE) by providing more and more layer of the requested chunk to the user. In this work, we are covering only the D2D part of the network, therefore, we consider that all users are getting equal rate on the cellular transmission. In such scenario, the users' QoE is improved by improving the D2D transmissions.



The optimization problem is designed as follow:

$$\max_{r_{ij}, q_i (\forall i \in N)} \sum_{s \in S} \sum_{i \in N} U_i^s \quad (5)$$

subject to

$$q_{i,s} \in Q_{i,s}, \quad \forall s \in S, \forall i \in N, \quad (6)$$

$$r_{ij} \leq R, \quad \forall i, \forall j \in N, \quad (7)$$

$$I_i \leq \eta. \quad \forall i \in N \quad (8)$$

Where constraint in eq (6) represents to select video quality from valid set of qualities. Constraint in eq (7) is to ensure that the DUE total rate does not exceed the total available rate i.e., we can not assign more than the available resource blocks. Constraint in eq (8) is to ensure that the interference on the DUE is less than the threshold η .

5. Proposed Solution

$q_{i,s}$ and r_{ij} in the optimization problem given in eq (5) are from discrete set and thus the optimization problem is combinatorial in nature which is not solvable for a practical size network and realistic videos.

First, we divide the network in disjoint groups (DJG) following solution given in [7] such that all the UE in a DJG can communicate with each other while the interference from transmission of other DJGs are less than the threshold η .

Then, we assign orthogonal frequencies to all the transmissions within one DJG. The UEs which are unable to get resources in a time window remains in waiting queue and are given preference in resource assignment in the next time window. A user is deleted from the waiting queue if his deadline for getting the segment has reached or going to end before the end of the current transmission window. After assigning resources to the DUEs which did not got resources in the previous window, the DUEs which achieves higher SINR are given preference in resource assignment. The proposed mechanism is present in detail in algorithm 1.

Algorithm 1: Proposed Solution

1. Input: DUEs list of video request, RBs
2. BS first searches the requested content within the requesting UE DJG.
3. **IF** (standby queue and priority waiting queue are empty) **THEN**
 - Go to step no: 14
4. **ELSE**
5. Assign RBs to DUE in the priority waiting queue
6. **IF** (found requested video in cache for a DUE) **THEN**
 - Inform the DUEs and put them in standby queue
 - Arrange standby queue in descending order of SINR
 - Assign resources to DUEs until $\sum_{(i,j) \in N} r_{ij} \leq R$
7. **ELSE**
 - Provide layer of the segment via cellular transmission
 - Put the remaining DUEs in priority waiting queue
8. **EndIF**
9. **IF** (DUE/CUE has completed video download) **THEN**
 - Remove DUE from stand by queue
10. **ELSEIF** (All the layer have been delivered to the DUE or deadline finished for the segment) **THEN**
 - Go to the next segment of the video
 - Put DUE to standby queue
 - Go to step no: 3
11. **ELSE**
 - Go to step no: 3
12. **EndIF**
13. **EndIF**
14. **EXIT**

6. Performance Evaluation:

In this section, we present a scenario-based performance evaluation for our proposed mechanism. We consider a typical cellular network environment in which there is a BS and 25 UEs. UEs are placed in the shape of grid with equal distance between them in a cell of 400x400 meters. We assume the whole cell as one DJG. At a given time window, we assume, 13 UEs are requesting UE and 12 are provider UEs. Requesters and Providers are randomly paired with each other. We assume all the users achieves the same gain on the cellular transmission and require 4 RBs to get a segment of the video. For the D2D transmission, UEs need 1 RB for transmitting one segment per 100 meters. Figure 3 shows the evaluation results for 8, 12, and 16 RBs. Our assumptions for the evaluation and fairness in the shape of waiting queue in our proposal make the results equal for all the UEs.

7. Conclusion and Future Work

In this paper, we presented layered video streaming in D2D enabled cellular network. The UE puts request for a video. The edge (BS/SBS) take care of providing the video continuously with maximizing the QoE by maximizing the provided video quality. We presented a heuristic algorithm to the combinatorial optimization problem. We presented a scenario based performance analysis. For our future work, we aim to extend our mathematical model and provide numerical analysis for realistic communication scenarios.

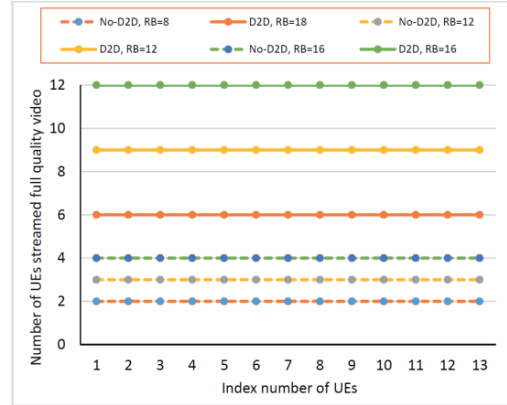


Figure 3 Scenario based evaluation

8. Acknowledgment

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