Socially-Aware SVC Video Caching in Information Centric Networking with D2D Communication

Saeed Ullah, Latif Ullah Khan, and Choong Seon Hong*

Dept. of Computer Science and Engineering, Kyung Hee University, Rep. of Korea

Email: {saeed, latif, cshong}@khu.ac.kr

Abstract

Caching the most suitable content at the right place is one of the most important issues in Information Centric Networks (ICN). In this paper, we have proposed to cache the content in the network on the basis of social connectivity of the users. Local popularity of a contact can be more important than the global popularity and the social connection between the users is an important parameter for considering local popularity of the content. Our cache decision, presented in this paper, gives weight to the content according to the connected users' social connectivity. Moreover, the baselayer and lower enhancement layers are given more weight than the upper enhancement layers of the SVC encoded video because of the higher popularity of the lower layers of SVC video. Base Station (BS) is responsible for making the cache decision and the users' device cache the content on the recommendation of BS.

1. Introduction

The fourth-generation of cellular network has exhausted the spectral efficiency of the cellular system and fifth-generation has further closed the door of any spectral enhancement by using massive MIMO and small-cells. Device-to-Device (D2D) communication is envisioned to further enhance the frequency re-use by short-range local transmissions [1-3]. Moreover, the modern-day smart user User Equipments (UEs) like smart-phone and tablets are equipped with computing capabilities and larger memories. Part of these memories can be used to cache the content and use it for D2D communication.

On the other hand, cache size is always been a scarce resource, especially for video contents. Caching the most important content has always been the focus of researchers in the field of Information Centric Networking (ICN) [4-8]. Most of the researchers in the literature consider the global or central popularity of the content, like the number of hits or rating by the users [5, 6] for their cache decision. However, local popularity for the contents can differ from the global rating of the content.

In this paper, we propose cache decision in the UEs for D2D communication and in the BS taking the users' social connectivity in the consideration. The BS cached the content its
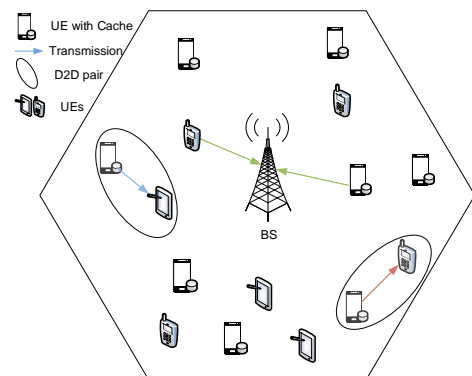

Figure 1: *Network Diagram*

own cache if the content belongs to the users who are spread in the network and there are fewer chances of being made a link for D2D communication. However, if the content belongs to socially connected users in close proximity then the content is cached in the UE's cache. In the evaluation, we have shown that the proposed mechanism achieves significant performance improvement.

2. System Design

Let G(V, E) is a social network graph in which V (vertices) represents users and E (edge) represents the social relationship among the users. Every content is related to the entity it is shared from, i.e., a YouTube channel the video is uploaded from, or a profile something is shared from on Facebook or

tweeted/retweeted on Twitter. Vertices having edges to the entity the video content is shared from is having a vital role in the cache our proposed cache decision.

Fig. 1 is showing network diagram of our proposed mechanism. The users are associated with a BS and the users with cache can cache the content and can provide it to other users under the supervision of the BS. When a UE is associated with the BS the BS extract its social connectivity. Here we assume that the either the UE's profile are public, in which case the BS can easily extract the information about the user's social connectivity or the user provide information about its social connectivity to the BS. Furthermore, the UE also provide list of the content already cached in it to the BS at the time of association. The BS maintain a virtual cache in which content cached in each UE are listed.

Our cache decision is a hybrid scheme i.e., BS recommend the content to cache that is requested by the UE with cache reactively or when a content is shared/uploaded by an entity that has followers in the proximity of UE with cache.

The Data packet contains one-bit field we call Cache Bit (CB), which is used for the cache decision in the UE. CB is set by the BS which we will discuss in next section. Communication scenario of the proposed mechanism is shown in figure 2.

3. Proposed mechanism

According to Content Centric Networking (CCN), there is a Data packet for every Interest packet. The detailed communication scenario is given in figure 2. The cache decision parameter C is defined as follow:

$$C = \frac{l}{L} * S * \frac{1/k_i^{\alpha}}{\sum_{m=1}^{M} 1/m^{\alpha}} \tag{1}$$

Where, α is the value of exponent that shows Zipf distribution's skewness, k_i is the rank of the content. M is the total video contents. L is the total layers in the H.264/SVC encoded video. Baselayer got the highest value and the enhancement layers are getting lower values as we go up in the layers hierarchy. S are the number of UEs registered for the content. S is subjected to the scope of the content communication i.e., if we consider caching the content in the cache of a UE then S are the number of UEs registered for the content in the communication range of UE, while if we consider caching at the BS then S are the no;
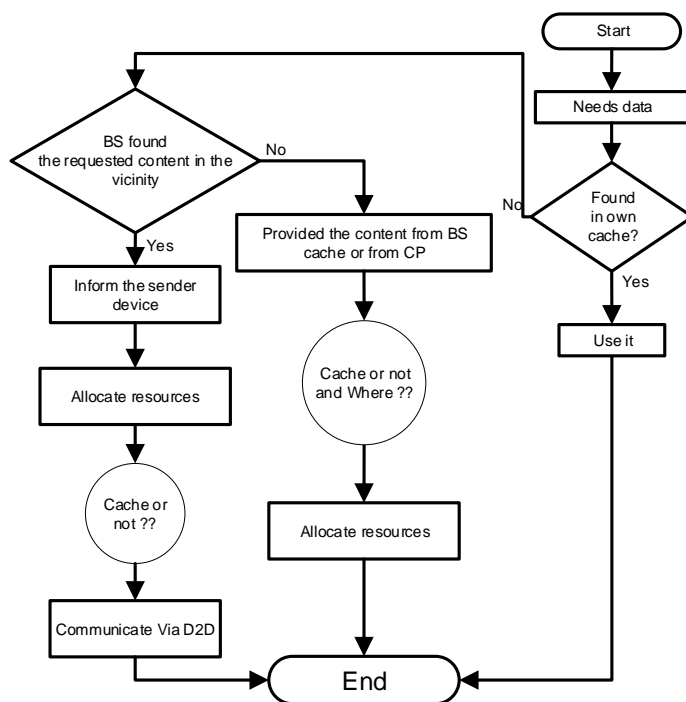

Figure 2: *Content providing mechanism*

of UEs registered for the contents in the whole network.

We propose to cache the content in the cache of UE if the UE is equipped with cache and value of C calculated in eq (1) is greater than the threshold θ, in such case BS set the CB value to 1 in the Data packet. When UE receives Data with CB = 1 then it caches the content. In case, the UE does not have cache or not enough UEs are in the vicinity or the video is not enough popular then the BS set the CB value to 0 in the Data packet. In such case, the UE does not consider the content for caching. The BS then consider caching the content in its own cache if the C value is greater than the threshold ∂. Otherwise, the content is not cached even in the BS cache. Our cache decision is presented in detail in algorithm 1.

4. Performance Evaluation

In this section, we present scenario-based performance analysis of our proposed cache management scheme. We consider a network of 100 users connected to a BS. The users are having 5 socially connected users on average ranging from 0 to 10. The video sequence under consideration is having 5 layers in which base-layer's size is 2 MB, second enhancement-layer is 1.5 MB and all other layers are of 1 MB each. Figure 3 is showing the achieved Peak Signal-to-Noise Ratio (PSNR) when there is no

other UE in range for making a D2D link then 1 and so on up to 8 socially connected UEs in the communication range.

Algorithm 1: *Cache Decision for H.264/SVC Video*

BS receives a request for a video chunk

BS finds the content and delivers it to the user

    IF (The requesting UE is having cache & $C \geq \theta$)

      THEN

        Mark the CB = 1

    ELSE

        Mark the CB = 0

    EndIF

    IF (The requesting UE does not have cache or $C \leq \theta$)

      THEN

        IF ($C \geq \partial$) **THEN**

          Cache the content in the BS

        ELSE

          Do not cache the content

    ELSE

      Do not cache the content

    EndIF

    IF (New content is published for which there is/are follower in the network) **THEN**

      IF ($C \geq \theta$ in a single communication domain)

        THEN

          Select a UE randomly make the CB = 1 and push the Data packet to randomly selected UE

      ELSE IF ($C \leq \theta$ in a single communication domain & in the network $C \geq \partial$) **THEN**

          Cache the content in BS

    ELSE

      Do not cache the content

    EndIF

---

5. Conclusion and Future Work

In this paper, we presented cache decision scheme for H.264/SVC encoded video in BS and UE's cache on the basis of social connectivity of the users. The proposed cache decision is a hybrid scheme in which the content are store reactively as well as proactively both in the BS and UEs. Our proposed cache decision is based on the users' social connectivity and the contents are given cache weight based on the source the content is originated from. Our proposed mechanism shows improved performance. In future we aim to make a mathematical model for our proposed cache mechanism and evaluate it on a real dataset.
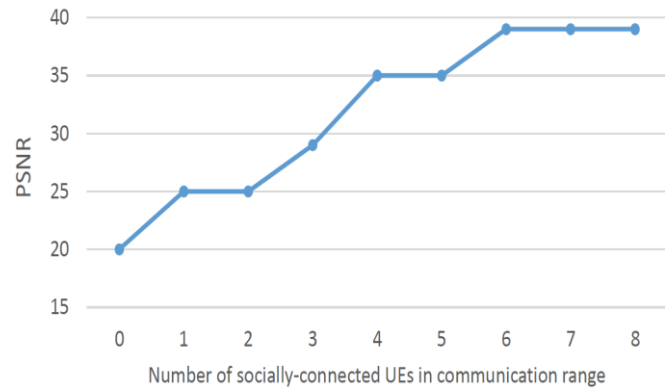
Figure 3: *Average quality of the downloaded video*

6. Acknowledgement

7. References

[1] S. M. A. Kazmi et al., "Resource management in dense heterogeneous networks," 17th Asia-Pacific Network Operations and Management Symposium (APNOMS), Busan, 2015, pp. 440-443.

[2] S. M. A. Kazmi, N. H. Tran, T. M. Ho and C. S. Hong, "Hierarchical Matching Game for Service Selection and Resource Purchasing in Wireless Network Virtualization," in IEEE Communications Letters, vol. 22, no.1, pp.121-124, 2018.

[3] S. M. A. Kazmi, N. H. Tran, Tai Manh Ho, Dong Kyu Lee and C. S. Hong, "Decentralized spectrum allocation in D2D underlying cellular networks," 18th Asia-Pacific Network Operations and Management Symposium (APNOMS), Kanazawa, 2016, pp. 1-6.

[4] Saeed Ullah, Kyi Thar, and Choong Seon Hong. "Management of scalable video streaming in information centric networking." Multimedia Tools and Applications 76.20 (2017): 21519-21546.

[5] Thar, Kyi, et al. "Efficient forwarding and popularity based caching for content centric network." International Conference on Information Networking (ICOIN), IEEE, 2015.

[6] Thar, Kyi, et al. "Hybrid caching and requests forwarding in information centric networking." 17th Asia-Pacific Network Operations and Management Symposium (APNOMS), IEEE, 2015.

[7] Ndikumana, Anselme, et al. "Network-assisted congestion control for information centric networking." 17th Asia-Pacific Network Operations and Management Symposium (APNOMS), IEEE, 2015.

[8] Ndikumana, Anselme, et al. "Novel Cooperative and Fully-Distributed Congestion Control Mechanism for Content Centric Networking." IEEE Access 5 (2017): 27691-27706.