Outband D2D Communication for Layered Video Delivery in ICN Enabled Cellular Network

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Abstract

D2D communication has brought a paradigm shift to cellular networks. Video streaming is always been a bandwidth killer for the networks. With high speed internet connectivity through advanced cellular networks, mobile users demand for watching high quality video is also increasing. In this paper we propose a model for offloading layered video streaming in cellular network with Information Centric Networking concept using outband D2D communication. The proposed mechanism makes D2D pairs on the basis of mutual benefits or benefits from the service provider. In case both the users watch the same video (like time shifted TV or live sports events etc.), they cooperatively schedule video offloading and sharing via outband D2D link to get higher quality video. In the analysis we have shown that our proposed mechanism increases network coverage throughput and hence QoE.

1. Introduction

Three-fourths (75 percent) of the world's mobile data traffic will be video by 2020 [1]. In the future of cellular network D2D is envisioned to increase the network coverage as well as provide better quality of service to the users [2] [5]. Moreover the current IP based Internet structure which is location specific is not efficient enough to cope with the future Users demand. To fulfill the increasing users demand a future Internet architecture that is called Content Centric Networking (CCN), an instance of Information Centric Networking (ICN), is introduced by van Jacobson [3] which changes the Internet to Information specific.

In ICN users initiate and maintain the communication by generating Interest message whenever it needs a piece of Data. Devices on the way, equipped with Content Store (CS), i.e., cache memory, provide the requested Data if it is present in the cache, otherwise they forwards the Interest towards the potential server following Forward Information Base. Devices (routers) aggregate similar Interest from different paths by maintaining a Pending Interest Table (PIT). Interested readers are referred to [3] for more details.

H.264/SVC encoded video provides scalability to users by encoding the video into multiple layers. There is a mandatory Base Layer (BL) and multiple optional Enhancement Layers (ELs). BL is capable of decoding video with the lowest quality independently while ELs are used to improve video quality.

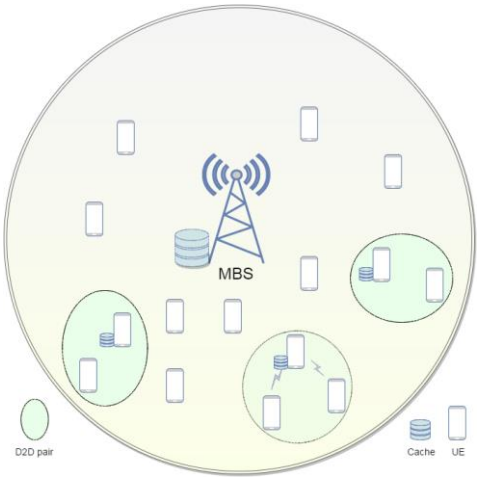

Figure 1: System diagram for outband D2D video offloading in cellular network.

In this paper we propose a model for cooperative downloading and sharing h.264/SVC encoded video in cellular network with Information Centric Networking concept using outband D2D communication. The proposed mechanism makes D2D pairs on the basis of mutual benefits or benefits for the service provider. In case both the users watch the same video (like time shifted TV or live sports events etc.), they cooperatively schedule video offloading and sharing via outband D2D link to get higher quality video by the participating nodes. In our analysis we have shown that our proposed mechanism increases network coverage and throughput.

2. System Architecture and Assumptions

Our proposed scheme can be applied to typical cellular network scenario as shown in figure 1. The

Algorithm 1: video downloading mechanism

A UE receives Interest for a video chunk:

If (the requested Data chunk is not present in the cache or the device battery is below ɣ) **then**
Remain quiet and don't send any reply
ELSE
Inform BS as well as the requesting device about the availability of the chunk in cache

If (the requesting node is watching the same video as the provider node) **then**
Schedule the download such that eq (1) and eq (2) are satisfied
ELSE
Negotiate with the BS/service provider for the benefits
Deliver the video to the requesting user via outband D2D link
EndIF
EndIF

network is consisted of a Base Station (BS) and mobile Users Equipment (UE), usually cell phones. As the future of Internet is envisioned to be information centric therefore, we are assuming the BS as well as the UEs are equipped with cache memory as well as they operate on CCN protocol for getting the required Data, as been discussed in section 2. UEs can use a portion of their SD card as cache memory.

UEs are battery devices and usually have limited data planes from the service providers, therefore they are always greedy in using their power. Majority of the proposal for the wireless devices take the assumption that all the devices cooperative for improving the social welfare, which is nonrealistic. In our this proposal the user will cooperate for providing the other users' requested Data either from its cache or downloading cooperatively (relay service) for the following two benefits:

i) User gets benefits from the service provider in the shape of free Data budget or reduction in the bill.
ii) The beneficiary user provide its relay services for downloading video for the benefactor cooperatively. In section abc we have discussed in detail this cooperation may further improve the QoE in case the beneficiary user also going to watch the same video.

3. Problem Formulation and Motivation for the Proposed Mechanism

In cellular network the users that are nearer to the BS or have less signal obstruction in between the users and BS receive higher strength signals, thus have lower error rate and get higher data rate due to using high rate of modulation [3]. While users that are far away from the BS or have obstruction between them and the BS are getting lower data rate because of using lower rate modulation. By making the UEs CCN enabled users can get the requested Data from nearby user(s) with higher data rate if the requested Data is present in their cache. This technique helps the operators by providing higher Quality of Experience (QoE) to their users as well as increase the network's coverage. Moreover, user can schedule cooperatively schedule offloading of the different layers of the video from the BS via cellular link and share it among them through D2D link, thus they will get better quality video by exploiting this D2D communication and cooperative downloading.

4. Proposed Layered Video Offloading Mechanism

In our proposal the scenario is such that all the communication is initiated by the users i.e., following CCN. The users are hearing other users' request that are in a specific range. If a UE receives an Interest from other UE and its remaining battery level is lower than a threshold ɣ or the requested chunk is not present in its cache then the receiver UE will remain quiet and will not send any reply. However, when the corresponding Data of the received Interest is present in the cache of the receiving UE, then it informs the BS as well as the requesting user about the availability of the requested chunk in its cache. Then the user negotiate with the user regarding the mutual benefits. If the requesting as well as the providing nodes are watching the same video (in case of time shifted TV or live sports broadcasting video) they schedule the cooperative download of the video. The user with higher cellular signal strength has to ensure the following two things.

i) Bandwidth Limit: The stronger user "i" assign the video download to the other user "j" according to the following formula:

$$(tR_{v_{kj}^{lm}} + \beta) \leq R_j \quad ---- (1)$$

Where t is the playback time of the video chunk, $R_{v_{kj}^{lm}}$ is the predicted rate of the chunk of video k of layer m to be downloaded by user j. R_j is the achievable rate of user j. β is the maximum error in video rate prediction. In other words user j is asked to download the video portion that don't exceed its bandwidth limit.

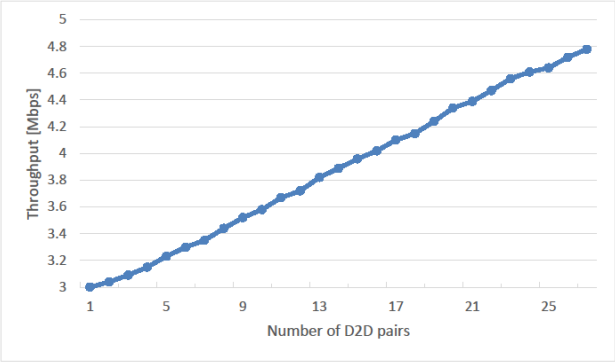

Figure 2: Average users throughput with D2D pairs.

ii) Layer download scheduling: In case both the users agreed for cooperative download, the following equation must be satisfied:

$$v_{kj}^{lm} \prec v_{ki}^{\ln} \text{----} (2)$$

Where v_{kj}^{lm} is the video k layer m to be downloaded by user j, while $v_{ki}^{\ln}$ is video k layer n to be downloaded by user i. Here, $m < n$ or in other words user j is asked to download the lower layers of the video so that it could use it for himself as well.

Thus user j will get the layers of the video downloaded from user i via D2D link will be bonus that will increase its received video quality and user i will use its cellular resources for downloading higher enhancement layers and get lower enhancement layers of base layer from the user j and hence will get higher quality video.

In case the two users in the D2D pair are not watching the same video then the video providing user will negotiate with the service provider for getting benefits from. The benefits it get will be in the form of free data bundle or reduction in the bill. The details of these benefits we leave for the future work. Proposed video retrieval or offloading mechanism is presented in algorithm 1.

5. Numerical Results

We assume a scenario of one BS and 100 mobile users that are moving randomly. Users generating requests for a video randomly from total of 100 video files. Popularity of the videos are Zipf distributed with parameter ($\alpha = 1$). One average users are getting data rate of 3 Mbps from the cellular network [6], while D2D link data rate varies between 4~10 Mbps [6] (depending upon the distance between users in the pair). We have numerically analyzed this system and the results are shown in figure 2. Here, we see that the user throughput is increased with increase in the number of D2D pairs.

6. Conclusion and Future Work

In this paper we presented a mechanism for layered video offloading in cellular network using outband D2D communication. Users in D2D pair gets benefits either from cooperatively downloading and sharing video via D2D link or benefits from the service provider for the cooperation. As a result of the proposed mechanism, the network coverage is increased and the users get high QoE. In future we aim to present more detailed description of the proposal and evaluate it through and more simulations.

7.Acknowledgement

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8. References

[1] Cisco Visual Net. Index: forecast update 2015-20 <http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile white-paper-c11-520862.html>

[2] Asadi et al. "A survey on device-to-device communication in cellular networks." Communications Surveys & Tutorials, 16.4 (2014)

[3] Van Jacobson et al. "Networking Named Content", CoNext, Rome, Italy, 2009.

[4] Schulman, Aaron, et al. "Bartendr: a practical approach to energy-aware cellular data scheduling." ACM international conference on Mobile computing and networking, 2010.

[5] Asadi, Arash, Vincenzo Mancuso, and Gupta Rohit. "An SDR-based Experimental Study of Outband D2D Communications." Infocom 2016.

[6] Asadi, et al. "On the compound impact of opportunistic scheduling and D2D communications in cellular networks." ACM int. conference on Modeling, analysis & simulation of wireless and mobile systems. 2013.

[7] Schwarz et al. "Overview of the scalable video coding extension of the H. 264/AVC standard." IEEE Tran. on Circuits and Sys. for Video Technology, (2007)