Analyzing Cache Storage Space Buying Strategies of Mobile Virtual Network Operator for Minimizing Loss

Kyi Thar, Thant Zin Oo, and Choong Seon Hong
Department of Computer Science and Engineering, Kyung Hee University.
Email: {kyithar, tzoo, cshong}@khu.ac.kr

Abstract

In the next generation network architecture, edge node such as base station temporary stores contents (video, music, etc...) and provides those stored content to users to reduce the network's traffic as well as service delay. In addition, because of network virtualization technology, physical resources such as cache storages are able to share among Mobile Virtual Network Operators (MVNOs). In this environment, if MVNO buys virtual cache storage space more than or lower than its needs, which will affect the profit of MVNO. Thus, in this paper, we observe suitable cache space buying strategies for MVNO to maintain its profit. So, we first expose the "Movie Lens-1M" dataset to understand the behavior of video contents request pattern. Then, we proposed three simple cache storage space buying strategies and analyzed those strategies with python based simulator.

1. Introduction

According to the Cisco Visual Networking Index, watching videos from wireless devices has been generating most of the Internet traffic and is forecast to continue to grow exponentially[1]. In order to handle the increasing Internet traffic, in-network and edge-network caching capability added to the next generation network architecture [2]. Additionally, because of Network Virtualization [3] technology, physical resources owned by Infrastructure Providers (InPs) such as cache storage spaces are able to share among Mobile Virtual Network Operators (MVNOs). Thus, with the help of in-network caching and virtualized cache space sharing, edge nodes (Base Stations (BSs) and Small-cell Base Stations (SBSs)) temporarily store video contents in their virtual cache space to satisfy user requests in the near future.

In this environment, if MVNO buys the cache space more than or lower than its need, which will degrade MVNO's profit. In this way, cache space buying decision to efficiently and effectively store contents become challenging issues, where the future user demand is unknown. Therefore, in this paper, we analyze Movie Lens dataset and expose suitable cache storage space buying strategies of MVNOs.

Our contributions can be summarized as follows:

- We expose the Movie Lens [4] 1M dataset and analyze the important features to get suitable cache space buying strategies.
- Based on analysis, we propose simple cache space buying strategies to minimize the loss of MVNO.
- Finally, validate the performance of proposed cache space buying strategies by utilizing Movie Lens dataset.

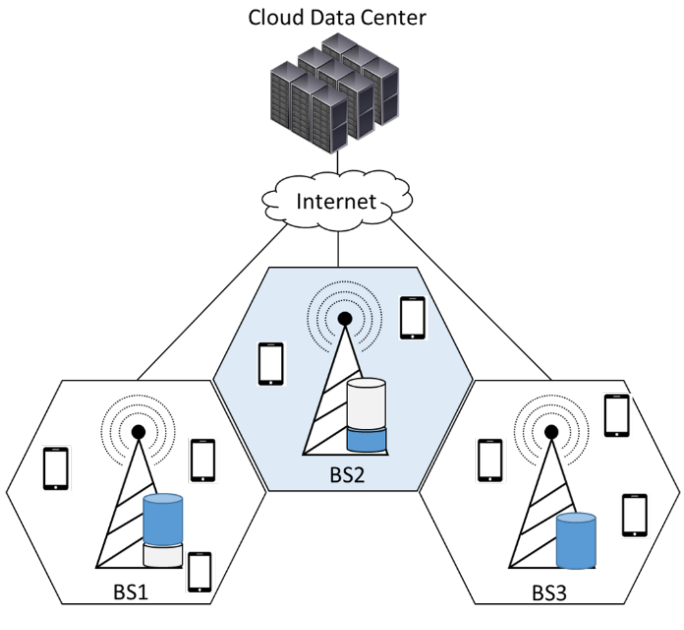

Figure 1 System Model

2. System Model

The system model of the proposed scheme is shown in Fig.1, where the infrastructures such as BSs are owned by one InP, and those BSs are attached to the cache storage. With the help of virtualization technology, physical cache storage at each BS can share among MVNOs as virtual cache storage space.

Every time t, each MVNO buy required virtual cache space for next time $t+1$ from InP. Each MVNO collects content's request information from each BS. In this paper, for the simplicity, we consider only one MVNO and one InP. At every time t (e.g. every night) MVNO buy a virtual cache storage space from InP based on collected information.

3. Exploratory Data Analysis (EDA)

The Movielens 1M dataset includes 6040 users and 1,000,209 ratings over 3706 movies. In addition, this dataset includes others information related to the users such as age, sex, occupation. Also, the data set includes movies related information such as released date and genre. In our case, we are interested in the relationship between the number of requests by users and the number of the unique content count from the dataset.

Thus, we extract the number of daily unique content count requested by users for one year (2015), which is shown in Fig.2. Fig.2 does not show any useful information for making a cache space buying decision.

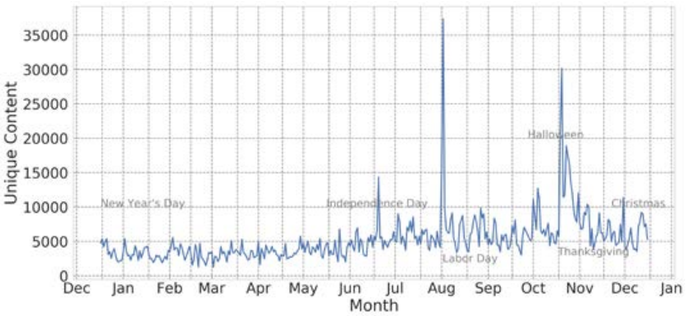

Figure 2 Unique content access pattern of year 2015

As shown in Fig.3, we extract the unique content count by mean of the month, where unique content counts are increasing from Feb to Aug, and decreasing again in Sep. The unique content count is increasing again from Sep to Nov.

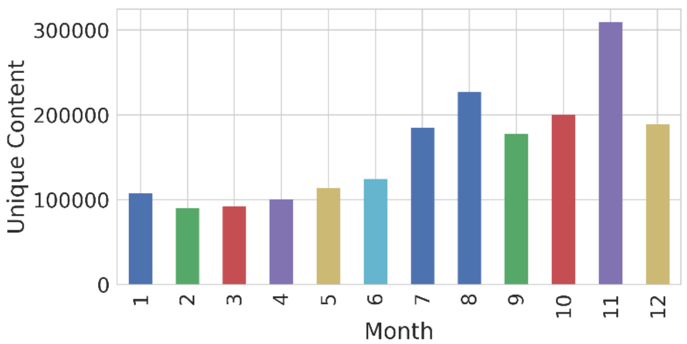

Figure 3 Monthly unique content count

Then, we explore the weekly unique content count pattern as shown in Fig.4, where the day is on the x-axis and start from 0(Mon) and end at the 6(Sat). The middle circle points show the mean values of the unique content count for each day in 2015. We found the pattern, where the unique content count is increasing from 3(Thu) to 0(Mon). Also, 6(Sun) and 0(Mon) higher content count than the other days. Thus, we should buy more cache space at the weekend than the others days.

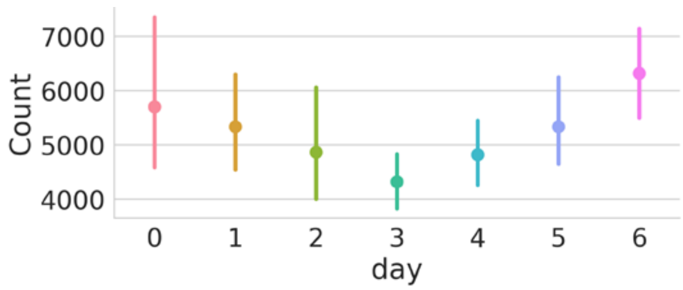

Figure 4 Weekly unique content count

In order to know, how much cache space we should buy in every day, we produce the histogram. From the histogram, we can analyze the distribution of unique content request per day for one year (2015). In this paper, we cannot show the weekday distribution and yearly distribution because of page limitation. The results from Fig. 5 shows that the highest probability for accessing unique content per day is around 2000 contents. Thus, if we buy cache space which fit 2000 contents can be balanced by the loss of MVNO but it is not an effective strategy. Therefore, we will find out different cache space buying strategies in next section.

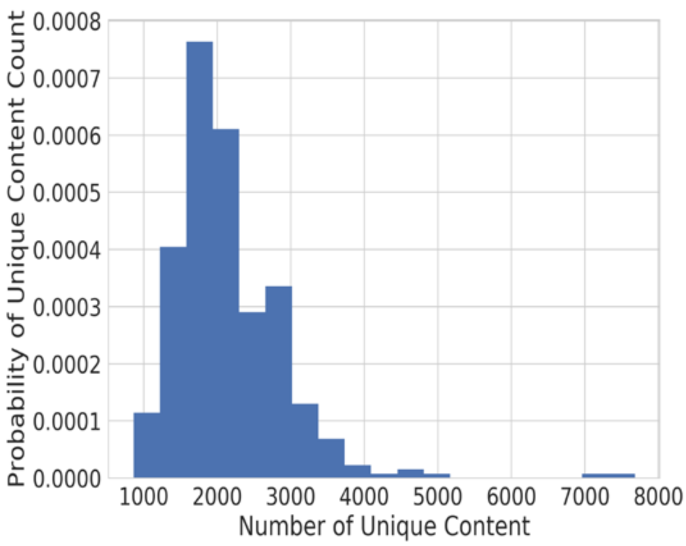

Figure 5 Histogram of unique content count per day

3.2. Cache Space Buying Strategies

In this section, we first define simple lost function of MVNO to measure the performance of buying strategies as follows

$$\boldsymbol{loss} = |\boldsymbol{b_t} - \boldsymbol{u_t}|, \quad (1)$$

where the cache size $\boldsymbol{b_t}$ is bought by MVNO at time t and $\boldsymbol{u_t}$ is the actual cache space usage at time t. Then, we define three strategies to buy cache space as follows,

$$\begin{aligned} \boldsymbol{exp_{max}} &= \boldsymbol{max}(\boldsymbol{count}[\boldsymbol{t}:\boldsymbol{t}+\boldsymbol{n}]), \\ \boldsymbol{exp_{min}} &= \boldsymbol{min}(\boldsymbol{count}[\boldsymbol{t}:\boldsymbol{t}+\boldsymbol{n}]), \\ \boldsymbol{exp_{mean}} &= \boldsymbol{mean}(\boldsymbol{count}[\boldsymbol{t}:\boldsymbol{t}+\boldsymbol{n}]). \end{aligned} \quad (2)$$

The first strategy chooses the maximum cache size among the point from time t to current time $t+n$. The second strategy chooses the minimum cache size among the point from time t to current time $t+n$. Final strategy chooses the average cache space size among the point from time t to current time $t+n$.

4. Performance evaluations

Finally, the performance of cache buying strategies are analyzed with python based simulator. Fig.6 shows the loss measurement of three strategies based on iteration, where results show that the mean strategy gives minimum loss in every iteration compared to others. On the other hand, the max strategy gives the highest loss.

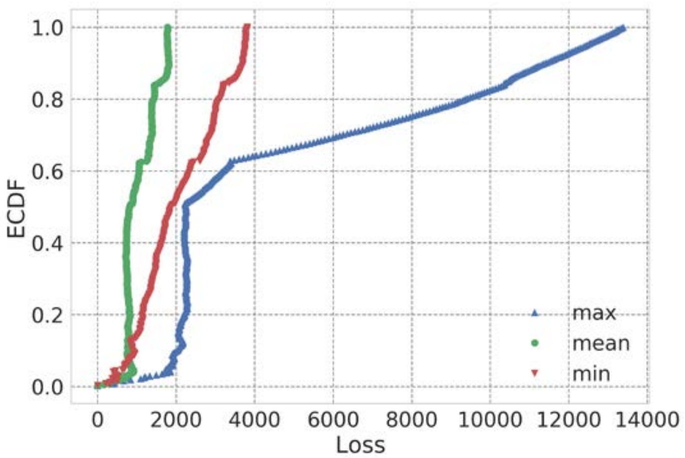

Figure 6 Loss comparison of three strategies

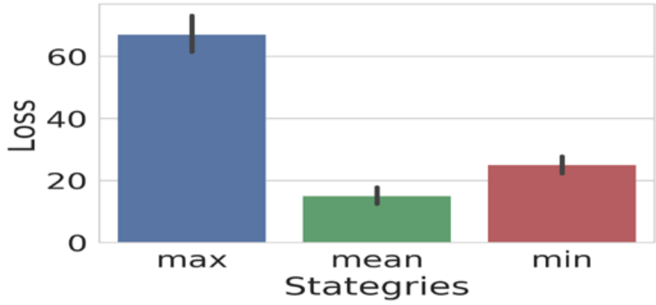

Figure 7 Average Loss comparison of three strategies

Then, we examine the average loss of three strategies in Fig.6, where the mean strategy gives us the best performance, min strategy give the second highest results and the max strategy give the worst results.

5. Conclusion

In this paper, we discussed three simple cache buying strategies to minimize the loss of MVNO. Among three strategies, choosing the average cache size is the best strategies for MVNO. As for the future work, we will work on learning based cache space buying strategy.

6. Acknowledgement

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*Dr. CS Hong is the corresponding author.

7. References

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