The Journal of Korea Information and Communications Society '14-10 Vol.39B No.10
http://dx.doi.org/10.7840/kics.2014.39B.10.684

Benefit of Multicast in Mobile MBMS

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ABSTRACT

In this work we investigate the benefit of multicast in the delivery of video data over the mobile MBMS network. In order to quantify the benefit in a practical aspect, this work proposes an analytic framework that employs a combined statistical and queuing model, where a queuing model represents the behavior of user's access to the video service and the statistical model captures the popularity of the video contents, via which we draw out a more realistic intuition for the expected benefit from multicast. Finally, we present results of numerical experiment that illustrates the validity of the proposed work.

Key Words : VoD, MBMS, mobile Internet, multicast, benefit

Ⅰ. Introduction

It is known that about 44% of the traffic in the present LTE (long term evolution) network is generated from video service, which implies that video traffic is the main point of concern in the operation and management of the mobile network [1].

It is also known that the connection holding time of the wireless internet is 2.5 times greater than that of the wired internet: the average time connected to a wired and wireless internet per day by a customer in Korea is 65 and 163 minutes, respectively [2].

One of the main reasons for the dramatic increase of mobile traffic is the increased usage of mobile video streaming services [3]. Park *et al.* argued that one of the killer business models in the future mobile service will be a combination of video on demand (VoD), social network service (SNS), and location-based service (LBS) [4]. LBS is considered to be very useful in the provision of multimedia broadcast multicast service (MBMS), because users have specific attributes in purchasing service concerned with location. For example, users can enjoy a real-time video for the on-going sports and concerts at the location they are participated in the events.

Recently, real-time TV contents as well as VoD are distributed by major mobile ISPs (Internet service providers). On January 27th 2014, KT launched an eMBMS over the LTE network [5], which is called the 'Olleh tv mobile'. In line with the penetration of eMBMS it is needed to investigate the effect of eMBMS on the performance of the network. To be specific, the following problems have to be resolved: (1) implementation of MBMS, (2) analysis for the performance and cost about MBMS, and (3) benefit of multicast in MBMS.

Now let us review literature that deals with the problems (1) and (2). Hasegawa *et al.* proposed a systematic architecture for IP-HDTV multicast [6], where they devise a mechanism for non-stop service availability and a control scheme for packet transfer.

Sun *et al.* analyzed the problems of P2P (point-to-point) mobile video system over wireless broadband networks [7]. They showed the difficulty of geo-localization (determination of geographical location), the obligation to manage a large number

※ This research is financially supported by Changwon National University in 2014~2015.
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논문번호 : KICS2014-08-289, Received August 4, 2014; Revised October 1, 2014; Accepted October 1, 2014

of sessions, the limit in the capacity of network resource, etc.

Zhang *et al.* proposed a baseline simulation method for the performance evaluation of MBMS using two typical models: P2P and P2MP (point-to-multipoint)[8], where they compared the spectral efficiency.

Alexiou *et al.* proposed an analytic model for the evaluation of the cost about the delivery of MBMS packets that considers air interface as well as the wired network[9].

Deb *et al.* proposed an analytic model to address the multicast resource allocation problem in a WiMAX system[10], where they argue that it is NP-hard and they evaluate the model via a simulation experiment.

On the other hand, to the best of author's knowledge, little work is reported about the problem (3). Therefore, this work focuses on the problem (3). Especially, this work proposes a theoretical framework about the benefit of multicast seen from the volume of traffic over the MBMS framework.

The rest of this work is composed as follows: In Section II, we present the attributes of mobile MBMS. In Section III, we present the popularity of video contents. In Section IV, we analyze the benefit of multicast. In Section V, the result of numerical experiment is shown. Finally, in Section VI, we summarize this work.

Ⅱ. Attributes of MBMS

MBMS is a streaming video service provided by an ISP [5]. Mobile MBMS is an MBMS provided by mobile ISP. Users can enjoy mobile MBMS via WiMAX or 4G wireless network such as LTE. Example of application in mobile MBMS includes newscast, weather forecast, real-time TV program, highlight of sports events, etc. An abstract architecture for mobile MBMS over LTE is shown in Fig. 1.

A network for mobile MBMS is composed of three areas: CP (contents provider), CN (core network), and RAN (radio access network).

CP is an area where contents are located. CP

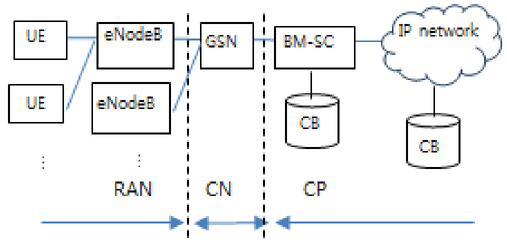

Fig. 1. Network architecture for mobile MBMS

owns CB (contents base) and BM-SC (broadcast/multicast service center), where CB is a storage for the contents and BM-SC is an interface between CP and CN which receives MBMS contents from the CP. BM-SC acts as a media server to a mobile network operator, and it transmits MBMS data to CN and manages customers (subscription & charging).

CN is composed of GGSN (gateway GPRS support node) and SGSN (serving GPRS support node). GGSN is a gateway to CN and SGSN is a gateway to RAN, and they are usually aggregated into a single node and called as a GSN (gateway server node). RAN is composed of eNodeB and UE (user equipment), where eNodeB provides services such as radio bearer service to UE, control MBMS, and management of mobility.

There are three modes of transmission for MBMS: unicast, broadcast, and multicast. Unicast transmits MBMS data in a P2P (point-to-point) manner, so that a connection has to be set up per-UE basis. This means that a video content has to be transmitted to each user independently, and it is very inefficient in using MBMS over the limited capacity of the downlink in LTE network.

Broadcast transmits MBMS data in a P2MP (point-to-multipoint) manner, which means that a content is broadcasted to all users irrespective of subscription. The problem in a broadcast is that ISP can achieve no revenue, because anyone can view the broadcasted TV program free of charge.

Multicast transmits data in a P2MP to limited users who subscribe to the service, so that a video content is distributed to a limited number of users. It is usual that PIM (protocol independent multicast) is used as a multicast protocol in IP network. A TV program in CB is transmitted to the network down to the edge of the wired network (GSN in Fig.1), and after that it is copied to a number of the same videos and distributed to corresponding eNodeBs that have MBMS customers [11]. Therefore, multicast can achieve network efficiency and revenue at the same time.

Since the function of the network at the physical layer is the same between broadcast and multicast, one can find that multicast is the most promising solution for the MBMS.

Ⅲ. Popularity of Video Contents

When it comes to describing the behavior of customers in mobile IPTV service, we have to take into account the following: *what content is more popular than the other and how many customers require the same content*. Among them the most important factor in characterizing the behavior of customer is the popularity of the contents.

It is usually known that there exist genuine attributes in the distribution of the popularity for the video programs in IPTV service [12]. A few video contents are very popular among many customers, whereas a large number of contents are viewed by a few customers, but it is not negligible. This is called *power law* or *long-tail,* and the corresponding probability distribution is called a Zipf-like distribution[11].

Let us show real data that illustrates the power law in popularity. Fig. 2 illustrates the number of download for the top 100 programs of an IPTV service at an ISP in Korea [13].

From the figure one can compute a pmf (probability mass function) $r(i)$ (i is the rank in the popularity that is ordered in the decreasing popularity, $1 \le i \le 100$) for the popularity of the download of the IPTV program. For example, $r(1)=0.0639$, $r(2)=0.0384$, $r(50)=0.0058$, and $r(100)=0.0027$ in Fig.2, from which one can observe a phenomenon of long-tail in pmf.

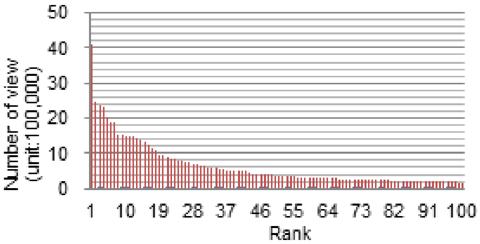

Fig. 2. Popularity of the contents

Ⅳ. Benefit of Multicast

First, let us present the basic concept about the benefit of multicast. After that we present the system probability for the number of customers who take part in multicast, via which we present the total state probability.

4.1 Benefit of multicast

It is generally known in the market of group purchasing that the larger the number of customers who select the same product is, the larger the benefit obtained from the purchase is, which implies that customers buy the product with lower price. This phenomenon is usually expressed by service externality and its benefit [14]. Service externality is the number of customers who select a product of the same condition, and external effect is the effect from the service externality such as monetary benefit.

Note that benefit may be also defined from the point of service provider, which implies that service provider can achieve lower cost (cost for operating as well as deployment of equipment) from higher service externality. For example, mobile ISPs can save network resource by introducing multicast instead of unicast when they provide users with video programs. In this case the benefit function may be defined by the ratio for the amount of data transferred by multicast as compared with that by unicast.

In order to present the benefit of multicast in MBMS the network architecture of MBMS has to be taken into account. Let us assume that J eNodeBs are multiplexed at each GSN and there is a single link between GSN and BM-SC. It is assumed that each eNodeB has K_j customers, where j, $1 \le j \le J$, is the index of an eNodeB. Note that it is trivial to assume a homogeneous number of customers for each eNodeB, so that we assume K_j=K. Then, there are a total of $J \times K$ customers who are subject to enjoy the MBMS, where we denote it as N=$J \times K$.

Recently, it is reported that the location of cache near the customers saves the operation cost as well as the traffic of the network as compared with a single point of storage at CP[15]. Note also that the location of contents has a vital impact on the benefit of multicast. Therefore, the benefit of multicast has to be defined by assuming different location of video contents.

First, assume that video contents are located at BM-SC of the CP. Then, we have two choices: First, unicast a single video between BM-SC and GSN and then multicast at GSN (let us call it *M-CB*). Second, multicast directly at BM-SC (let us call it *U-CB*), which is de facto unicast.

For each case, we have the following formulae for the effective benefit: $\epsilon_{M-CB}(J)$ and $\epsilon_{U-CB}(N)$ for *M-CB* and *U-CB*, respectively.

$$\begin{aligned} \epsilon_{M-CB}(J) &= (1+J)\omega \\ \epsilon_{U-CB}(N) &= N\omega \end{aligned} \tag{1}$$

where ω is the unit benefit and it corresponds to the volume of traffic.

Now let us define a benefit function as a relative benefit that is obtained from multicast as compared with that of unicast. Then, we have the following formula, B_{CB} for the benefit function:

$$B_{CB} = \frac{\epsilon_{U-CB}(N)}{\epsilon_{M-CB}(J)} = \frac{N}{1+J} \tag{2}$$

Second, consider the situation of video contents that are located at GSN or eNodeB, where the former is more general and we focus on it. In that case, a single video content is delivered a priori to GSN (in this case GSN acts as a *cache*). We have two choices for the transfer of the video to the customers: First, unicast a single video between GSN and eNodeB and then multicast at eNodeB (alias *M-CH*). Second, multicast directly at GSN (alias *U-CH*), which is in fact a unicast.

For each case, we have the following formulae for the effective benefit: $\epsilon_{M-CH}(J)$ and $\epsilon_{U-CH}(N)$ for *M-CH* and *U-CH*, respectively.

$$\begin{aligned} \epsilon_{M-CH}(J) &= J\omega \\ \epsilon_{U-CH}(N) &= N\omega \end{aligned} \tag{3}$$

In the same way, we have the following formula, B_{CH} for the benefit function when the contents are stored at a cache:

$$B_{CH} = \frac{\epsilon_{U-CH}(N)}{\epsilon_{M-CH}(J)} = K \tag{4}$$

Summarizing our results (2) and (4), one can find that, if $L >> 1$, B_{CB} converges to B_{CH}, and the benefit of multicast increases as the scale of the network and the service externality increases. This is the most promising phenomenon of multicast.

4.2 State probability and expectation

Let us compute a probability for the number of customers in the system in equilibrium. Let N be the number of customers who subject to enjoy MBMS. If N is sufficiently large, we can assume that the arrival of request for the MBMS follows Poisson distribution (mean=λ).

It is considered that the mean holding time of an MBMS session follows exponential distribution (mean=$1/\mu$). Then, the mean system load is given by $\rho = \lambda/\mu$.

It is assumed that the system has enough service capacity and buffer space to accommodate the customers. Then we can model the MBMS system as an $M/M/\infty//N$ queue.

For the $M/M/\infty//N$ queue we have the following formulae for the arrival and departure of customers at system state n :

$$\begin{aligned} \lambda_n &= \begin{cases} \lambda(N-n), & 0 \le n \le N \\ 0, & else \end{cases} \\ \mu_n &= n\mu, 1 \le n \le N \end{aligned} \tag{5}$$

Let $\pi(n)$ be the probability that the system is in state n $(0 \le n \le N)$ in equilibrium. By using the analysis of birth and death process in queuing theory[16], we obtain the following formula for $\pi(n)$.

$$\pi(n) = \binom{N}{n}\frac{\rho^n}{(1+\rho)^N} \quad (6)$$

Now let us define the probability that a group of *n* customers watch the *i-th* most popular video by multicast. Since we have already obtained a pmf *r(i)* $(1 \le i \le L)$ for the *i-th* most popular video in Section III, we can obtain a pmf *s(n,i)* for selecting the *i-th* most popular video by a group of *n* customers $(0 \le n \le N)$, which is given as follows:

$$s(n,i) = \pi(n) \times r(i) \quad (7)$$

Now one can compute the expected value for the benefit of multicast by selecting the *i-th* most popular video, which is noted as $\beta(i)$ and is given as follows:

$$\beta(i) = \sum_{n=0}^{N} s(n,i) \times B_X(n), 1 \le i \le L \quad (8)$$

where $B_X(n)$ denotes a benefit function that is achieved by multicast, where the lower index *X* denotes *CB* or *CH* depending on the location of the contents (See formulae (2) and (4)) and *n* inside a parenthesis is the service externality, which varies from *0* to *N*.

Finally, the total expected value for the benefit of multicast that can be achieved by taking into account all video contents, which is called a total benefit and denoted as B_T, is given as follows:

$$B_T = \sum_{i=1}^{L} \beta(i) \quad (9)$$

V. Experiment and Remarks

In order to evaluate the validity of the proposed model let us show a simple example with the following system parameters: First, we assume that video contents are located at a cache. The analysis for the case of storage located at the CB is the same. We used the data in Fig.2 as a basis for computing the pmf *r(i)*. Without loss of generality, it is assumed that $\omega = 1$, which implies that benefit is defined by a unit volume of data.

Fig.3 illustrates the expected value for the benefit by selecting the most popular video as a function of the offered load varying from 0.1 to 0.9 for the three cases of the service externality, where *N=1* corresponds to a basic benefit for the transfer of a single video content.

Note that the expected benefit increases in very steep manner as the service externality increases, which is a promising result. It is trivial to compute the expected benefit for the second or less popular videos, which is not shown in this work for the purpose of simplicity.

Now let us compute the total benefit from multicast. To do that, we assume that the ISP is interested in the benefit from a different number of videos such that the total expected benefit from the top 10 most popular or from the whole number of videos (100 videos), which is useful in a targeted-marketing or determination of the location of the cache. Fig.4 illustrates this result as a function of the offered load. The basic parameters are the same as in Fig.3 except N=10.

One can find that benefit from a few number (here, it is 10) of the popular videos occupy a very large portion of the total benefit, so that multicast is needed even for a few number of videos.

One more point that is needed to be noticed from

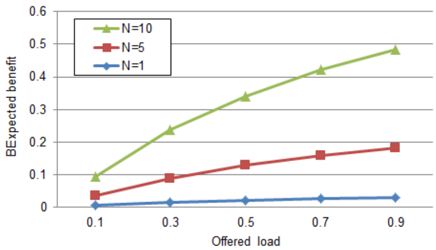

Fig. 3. Expected benefit of selecting the most popular video

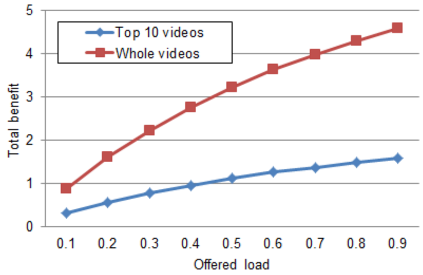

Fig. 4. Total expected benefit

Fig.4 is that the benefit of multicast is much more promising to the ISP as the scale of the network and the volume of traffic increases.

Ⅵ. Conclusion

In this work we proposed a new theoretic framework for the benefit of multicast in mobile MBMS. To be specific, we introduced two mathematical models that describe the concept of the power-law popularity of watching the video program as well as a function that describes the benefit of multicast in MBMS. This is considered to be novelty of this work that can be found nowhere.

This work is just a step toward many works for the analysis of the benefit of group watching in the future mobile IPTV service. To do that, we have to accumulate data on the behavior of users when mobile IPTV service is spread in a wide scale. We also have to devise a more effective method to represent the benefit of multicast in mobile MBMS for diverse types of network architecture.

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