Bargaining and Peering between Network Content/Coverage Providers

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Abstract. Both content quality and market coverage have significant impacts on a network content provider's revenue. In this paper, we present a preliminary study on how providers' cooperation and adoption of special content can affect the content quality and market coverage. We first consider a baseline case, where providers have static contents and do not cooperate. We derive the providers' coverages based on the quality of the contents and user subscription fees. Then we consider how cooperation and content sharing can help providers to improve their revenues. The key insight is that cooperation will be desirable when the providers' total revenue is increased and properly shared by an inter-provider financial transfer. In the case of linear advertisement functions, cooperation will happen when providers have different abilities in generating advertisement revenue and have proper subscription fees. We further consider the dynamic content case, where a provider can introduce some high quality special content for a short amount of time to attract users to switch from one provider to the other. We show that the switching cost, the valuation of content, and time discount factor all play important roles in deciding the benefit of special content.

Keywords: Network Content Providers, Content Coverage, Peering, Bargaining, Cooperation.

1 Introduction

High quality contents attract great interest from users, and can significantly increase the market coverage of *network content providers*. This in turn will increase the providers' advertisement and subscription incomes. One way for a network content provider to obtain high quality contents is to cooperate (or peer) with other providers and share contents. However, peering agreements are not always easy to reach. For example, Google TV, a new Internet-connected television platform, aims at providing users with new experiences of enjoying both traditional TV and web contents [1]. But some content providers (*e.g.*,

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Fig. 1. Network architecture among advertisers, network content providers, and end users

NBC and ABS in the U.S.) choose to block Google TV from accessing their TV programs. These content providers are afraid that this new technology may influence advertisers' choice of advertisement platforms (*e.g.*, Google TV vs. NBC's website) and reduce their advertisement incomes. A proper financial agreement between Google and the content providers may resolve this issue. Besides regular contents, there are some special contents (*e.g.*, world cup programs) that can attract many users during a certain period of time, and can be used as a powerful tool for providers to gain additional market share. The 2010 world cup broadcasting right issue in Hong Kong showed how fiercely content providers bargain over the special content delivering right [2]. The official broadcast right holder (iCable in Hong Kong) wanted the content to reach a bigger coverage together with its own advertisement. While other content providers (*e.g.*, TVB and ATV) wished to purchase the broadcasting right without the advertisement from iCable. A final agreement was reached which led to a win-win situation of both sides. In a third example, mobile TV program providers want to reach a large audience. However, indoor users typically have difficulty in accessing the mobile TV programs with a high quality due to a poor cellular signal receptions. Owners of large office buildings and shopping malls may help to "amplify" the signals through special equipments, and receive payments from the mobile TV providers for providing the extra coverage.

In this paper, we are motivated by the above three examples and want to study the interactions among multiple network content providers over content, coverage, and the possible strategies of cooperation. We will assume that network content providers obtain revenue through two approaches: advertisement income based on the agreement with advertisers and the market coverage, and subscription income based on the content quality and the subscription fees. The network architecture is illustrated in Fig. 1.

Many papers have studied network providers' strategies on maximizing revenues. Some studies (*e.g.*, [3]-[5]) focused on analyzing how to choose contents and determine advertisement lengths to attract users. Other results (*e.g.*, [6]-[7]) focused on how to increase revenue through either an advertisement-sponsored only approach or a subscription-and-advertisement-sponsored approach. However, none of the prior results have considered the cooperation among providers. Another line of research investigated the cooperation issues among providers. Reference [8,9] examined the incentive for ISPs to interconnect and developed Shapley value based revenue distribution mechanisms. Reference [10] examined the optimal pricing strategies for content delivery. Reference [11] considered rate allocation of ISPs with content providers' participation. However, most of these results assumed that each user has a fixed subscription to one provider and can not switch to different providers. Also, none of them have taken the advertising income into account during the cooperation. In our paper, we consider the interactions of advertisers, network providers, and users, where users may switch between providers depending on the contents and subscription fees.

In our paper, we will focus on the interactions of two network content providers in three cases. In the first baseline "static" case, both providers have fixed quality contents over time and they do not cooperate with each other. We will examine the users' subscription choices and the corresponding market share. Then we look at the second "cooperation" case, and study how cooperation can increase the providers' revenues with static contents. In the third "dynamic" case, we will consider how the introduction of a special content will impact the users' subscription choices and the providers' revenues.

Our main results and contributions are as follows:

- *General Network Model:* We present a model that captures the interactions among advertisers, network content providers, and users interact, and explain how users choices influence providers' content strategies and revenues.
- *Win-win Cooperation Agreement:* We propose a Nash bargaining based cooperation framework between providers, by considering the changes of content, advertisement, and coverage with the cooperation. We characterize the necessary condition for cooperation to happen, and show that a provider's bargaining power depends on its capability of generating advertisement revenue.
- *Impact of Dynamic Content:* One-time special content induces users to switch providers. We show how the switching cost, content evaluation, and time discount factor together determine a user's subscription decision and the providers' revenues.

The rest of the paper is organized as follows. Section 2 presents the static baseline model and Section 3 shows the cooperation strategy of providers through bargaining. The impact of dynamic content without cooperation between providers is given in Section 4. We conclude in Section 5 and summarize the future work directions.

2 A Static Baseline Model

We consider a duopoly market of two network providers: A and B. Each provider has a dedicated advertiser, who pays the provider advertising fees based on the provider's coverage. A provider's coverage depends on the number of users subscribing to its service. A provider can attract subscribers by high quality contents or a low monthly subscription fee.

2.1 Content Qualities and Subscribing Fees

We consider a period of T time slots, where each time slot has a unit length (*e.g.*, representing one month of time). The content quality of a provider $i \in \{A, B\}$

in time slot $t \in \{1, \dots, T\}$ is q_{it}. In this section, we assume that both providers have *static* contents, *i.e.*, $q_{it} = q_{it'} = q_i$ for any $t, t' \in \{1, \dots, T\}$ and both $i = A$ and $i = B$. Without loss of generality, we assume that provider A has a more popular content, *i.e.*, $q_A \geq q_B$. This may reflect the fact that provider A has a larger budget and can purchase higher qualities contents than provider B. We will come back to the budget issue in Section 4.

During each time slot, provider $i \in \{A, B\}$ charges each of its subscriber p_i. As provider A has a better content, it can charge a higher subscribing fee, *i.e.*, $p_A > p_B$.[1] *We further assume that both p_A and p_B are fixed throughout this paper.* This allows us to focus our study on the impact of content choices and provider competitions. In our future work, we will further discuss how providers optimize their subscription fees in a game theoretical setting.

2.2 Users' Utilities

Users may achieve different satisfaction levels by consuming the same contents. We characterize a user with two parameters: θ representing the user's valuation of the content quality, and δ representing the user's time discount factor over future contents. A user's total utility of subscribing and consuming contents from provider $i \in \{A, B\}$ over T time slot is

$$U(\theta, \delta) = \theta \sum_{t=1}^{T} \delta^{t-1} q_{it} - p_i T. \tag{1}$$

For a user who is indifferent of choosing either provider, we have the following relationship between θ and δ:

$$\theta \sum_{t=1}^{T} \delta^{t-1} q_{At} - p_A T = \theta \sum_{t=1}^{T} \delta^{t-1} q_{Bt} - p_B T. \tag{2}$$

Based on (2), we can compute the boundary evaluation $\theta^*(\delta)$ as a function of δ, which is illustrated in Fig. 2. Users with parameters (θ, δ) below the boundary will choose to subscribe to provider B, while the users above the boundary will subscribe to provider A.

2.3 Providers' Coverages and Revenues

For the rest of the analysis, we assume that both θ and δ are uniformly distributed in $[0, 1]$. Without loss of generality, we normalize the total users population to be 1. Then the area under the boundary represents the market share

[1] Assume this is not true and $p_A \leq p_B$. Then all users will choose provider A, who offers a better content with a lower fee. Provider B will have no subscribers and will be out of the market. This is apparently not an interesting case and will not be further discussed in this paper.

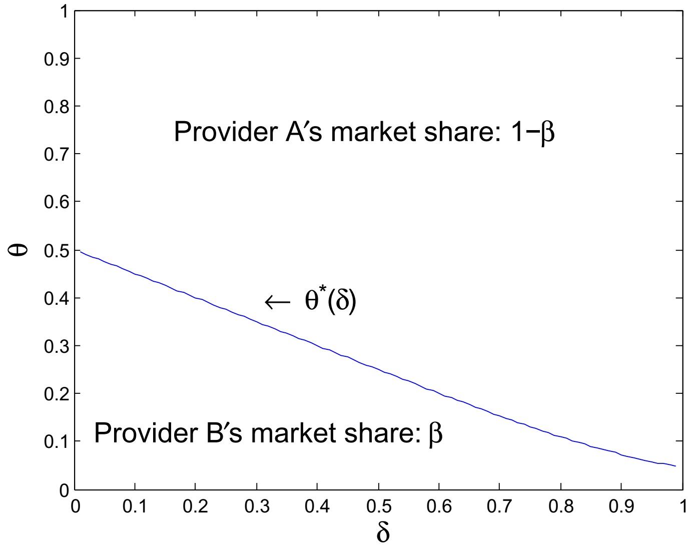

Fig. 2. Two providers' market shares

of provider B (denoted as β), and the provider A has a market share of $1-\beta$:

$$\text{Provider } A\text{'s coverage} : 1-\beta = 1-\int_0^1 \frac{(p_A-p_B)T}{\sum_{t=1}^T \delta^{t-1}q_{At}-\sum_{t=1}^T \delta^{t-1}q_{Bt}}d\delta, \quad (3)$$

$$\text{Provider } B\text{'s coverage} : \beta = \int_0^1 \frac{(p_A-p_B)T}{\sum_{t=1}^T \delta^{t-1}q_{At}-\sum_{t=1}^T \delta^{t-1}q_{Bt}}d\delta. \quad (4)$$

A provider's revenue includes both the users' subscription fee and the advertisement fee. We assume that provider $i \in \{A, B\}$ has a advertisement revenue function $f_i(\cdot)$ per time slot. Here $f_i(\cdot)$ is an increasing function of its market share. If there are no users accessing the contents, no advertisers will pay for the advertisement. Thus $f_i(0)=0$. The two providers' revenues over T time slots are

$$\pi_A = (f_A(1-\beta)+p_A\cdot(1-\beta))\cdot T, \quad (5)$$

$$\pi_B = (f_B(\beta)+p_B\cdot\beta)\cdot T. \quad (6)$$

2.4 Content Procurement Strategies

Each provider may change its revenue through contents procurement.[2] We consider two possibilities in the next two sections: peering between providers to share contents and increase coverage (Section 3) and introducing special content to attract users to switch providers (Section 4).

[2] Recall that we have assumed the subscribing fees p_A and p_B are fixed in this paper.

3 The Peering and Bargaining of Providers

3.1 Peering Agreement

When two providers cooperate (or peer) with each other, we assume that one provider will purchase the *whole* content from the other provider. Since provider A has the better content (*i.e.*, $q_A \geq q_B$ as assumed in Section 2), provider A will be the seller and provider B will be the buyer.

However, two providers have different concerns when peering. From A's point of view, it wishes to deliver both the content and its advertisement in B's network, so as to increase the advertisement revenue from its dedicated advertiser. A also wishes B to pay for the usage of the content. From B's point of view, it wishes to carry its own advertisement in order to get payment from its own dedicated advertiser. B also wishes A to pay for the additional coverage after peering with B.

Next we describe a general peering agreement. When peering, provider A and B will deliver the same content (*i.e.*, the original content of provider A). As for advertisement, provider A will deliver its own advertisement. Provider B delivers α portion of A's advertisement and (1-α) portion of its own advertisement. Finally, B pays provider A a one-time payment c for peering over T time slots, where c can be either positive or negative. Figures 3 and 4 illustrate two providers' contents and advertisements with and without peering. The bargaining variables are the advertisement ratio α and payment c. Figure 5 illustrates this bargaining process.

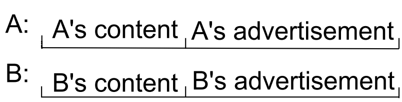

Fig. 3. Two providers' contents and advertisements without peering

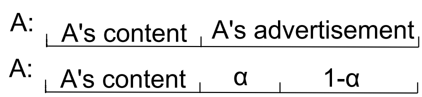

Fig. 4. Two providers' contents and advertisements with peering

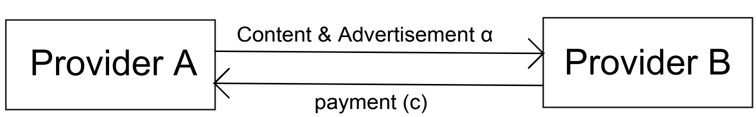

Fig. 5. Bargaining model

3.2 Change of Coverage

Now let us consider how users change their subscriptions when providers peer. Since now both providers have the same contents and provider B charges a lower price $p_B < p_A$, then all users will choose to subscribe to provider B.[3] Provider

[3] Here we assume that all users are freely to choose. This may not be the case where users already sign contracts with their providers. The additional switching cost because of this will be further discussed in Section 4.

A will get zero subscriber. However, notice that since α part of provider A's advertisement is delivered through B, then provider B's coverage also contributes to the advertisement revenue of A.

3.3 Providers' Revenues

Now let us compute the providers' revenues with peering. For provider A, its advertisement can reach all users with α fraction of the time. Hence, provider A's revenue with cooperation is

$$\pi_A^c(\alpha, c) = \alpha f_A(1)T + c. \tag{7}$$

For provider B, it can only deliver its own advertisement to its own users with $(1 - \alpha)$ fraction of the time. Thus, its revenue with cooperation is

$$\pi_B^c(\alpha, c) = (1 - \alpha)f_B(1)T + p_B T - c. \tag{8}$$

3.4 Nash Bargaining Problem

Next we model the bargaining problem based on the Nash bargaining solution [13], which is the unique bargaining solution that satisfies the axioms of *Pareto efficiency*, *symmetry*, *invariance*, and *independence of irrelevant alternatives.*

Definition 1. *A cooperation strategy* (α^*, c^*) *is a Nash bargaining solution if it solves the following problem:*

$$\mathit{maximize}_{\alpha \in [0,1], c} \quad \left(\pi_A^c(\alpha, c) - \pi_A\right) \cdot \left(\pi_B^c(\alpha, c) - \pi_B\right), \tag{9}$$

where π_A *and* π_B *are the revenue obtained without cooperation as in (5) and (6).*

It is clear that both providers should achieve revenues no worse than their non-cooperative revenues (*i.e.*, π_A and π_B) at the Nash bargaining solution. Otherwise, at least one provider does not have the incentive to bargain. This means that a cooperation agreement can be achieved if and only if the following condition holds:

$$\alpha f_A(1) + (1 - \alpha)f_B(1) > f_A(1 - \beta) + f_B(\beta) + (p_A - p_B)(1 - \beta). \tag{10}$$

With a proper choice of c, condition (10) can ensure that both providers get better payoffs through cooperation.

The optimal solution of (9) depends on the revenue functions $f_A(\cdot)$ and $f_B(\cdot)$. As an illustrative example, we consider linear advertisement revenue functions $f_A(x) = k_A \cdot x$ and $f_B(x) = k_B \cdot x$. Higher values of k_A and k_B lead to higher values of advertisement revenue with the same user coverage. Next we summarize the optimal solution of (9) depending on three possible relationships between k_A and k_B, with detailed proofs given in [14].

Scenario 1. $k_A = k_B$.

In this case, both providers have the same advertisement revenue function. The advertisements from both advertisers are equally important. If we plug $k_A = k_B$ into condition (10), then the left hand side (LHS) equals k_A and the right hand side (RHS) equals $k_A + (p_A - p_B)(1-\beta)$. Since $p_A > p_B$, we know that the LHS actually is less than RHS, and thus condition (10) does not hold. This means that providers will not choose to cooperate in this case.

Scenario 2. $k_A > k_B$.

In this case, provider A has a stronger ability in generating advertisement revenue than B. We can show that the optimal advertising strategy is $\alpha^* = 1$, in which both providers deliver the same advertisement originally belonging to provider A. With $\alpha^* = 1$, condition (10) becomes

$$k_A > k_A(1-\beta) + k_B\beta + (p_A - p_B)(1-\beta),$$

which means that the subscription fees p_A and p_B need to satisfy

$$p_A - p_B < \frac{(k_A - k_B)\beta}{1-\beta}$$

so that the providers want to cooperate. When the providers want to cooperate, we can further show that the optimal payment strategy c^* from provider B to provider A is

$$c^* = \frac{1}{2}\big((p_A + p_B)(1-\beta) - (k_A + k_B)\beta\big) \cdot T, \tag{11}$$

which can be either positive or negative. For example, if the revenue income is much larger than the user subscription fee, *i.e.*, $(k_A + k_B)\beta > (p_A + p_B)(1-\beta)$, then $c^* < 0$. This is because provider A's increase in advertisement income with cooperation is much larger than provider B's revenue increase by getting more subscribers. Then provider A should share the additional income with B.

Scenario 3. $k_A < k_B$.

In this case, provider A has a weaker capability in generating advertisement revenue than B. We can show that the optimal advertising strategy is $\alpha^* = 0$, in which the two providers deliver their own advertisements. With $\alpha^* = 0$, condition (10) becomes

$$k_B > k_A(1-\beta) + k_B\beta + (p_A - p_B)(1-\beta),$$

which is equivalent to

$$p_A - p_B < k_B - k_A,$$

which can be satisfied under proper values of p_A and p_B. When the providers want to cooperate, we can further show that the optimal payment strategy c^* from provider B to provider A is

$$c^* = \frac{1}{2} \cdot \big(k_A + k_B + p_1 + p_2\big)(1-\beta) \cdot T > 0.$$

In this case, provider A loses all the subscribers and can not get any advertisement revenue. As a result, provider B should compensate A's loss.

4 Impact of Dynamic Content

In this section, we consider how a provider can change its coverage (and thus the revenue) by introducing some special content (*i.e.*, content with a very high quality) over a short time period.

For a fair comparison, we assume that each provider has a finite budget. Introducing (purchasing) a special content in one time slot will decrease the content quality of the remaining $T-1$ time slots. This means that the content will become "dynamic" over the entire T time slots.

Without loss of generality, we assume that provider B introduces a special content with a high quality $q_s > q_A$ in the first time slot. As a result, the content quality for the remaining $t \in \{2, \ldots, T\}$ slots reduces to q'_B. Assuming a linear relationship between the budget and the content quality, then the finite budget constraint means that

$$q_s + (T-1)q'_B = Tq_B. \tag{12}$$

Here q_B is the static content quality introduced in Section 2. Figure 6 illustrates the change of provider B's content qualities with and without the special content.

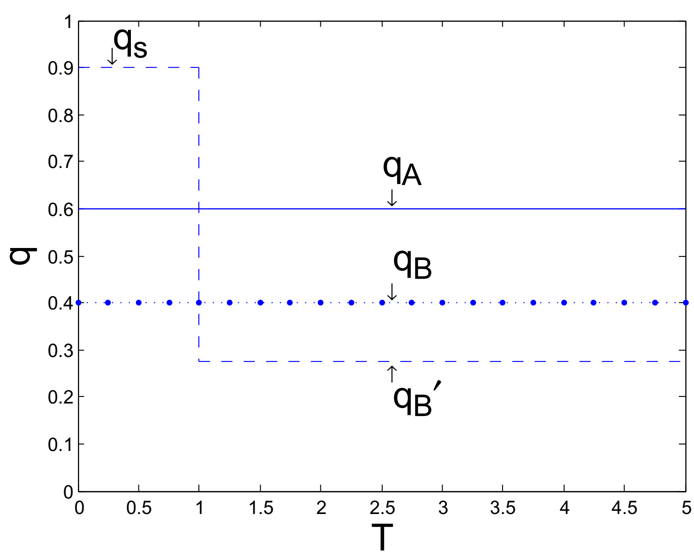

Fig. 6. Dynamic change of Content

Now let us consider if any user wants to switch from provider B to provider A after the special content is introduced at provider B. Recall that the utility of a user subscribing to provider B is

$$U_{B,static} = \theta \sum_{t=1}^{T} \delta^{t-1} q_B - p_B T$$

before introducing the special content and

$$U_{B,dynamic} = \theta q_s + \theta \sum_{t=2}^{T} \delta^{t-1} q'_B - p_B T$$

after introducing the special content. The utility change is

$$\begin{aligned} U_{B,dynamic} - U_{B,static} &= \theta q_s + \theta \sum_{t=2}^{T} \delta^{t-1} q'_B - \theta \sum_{t=1}^{T} \delta^{t-1} q_B \\ &= \theta \left(q_s - q_B + \sum_{t=2}^{T} \delta^{t-1} \left(q'_B - q_B \right) \right) \\ &\geq \theta \left(q_s - q_B + (T-1) \left(q'_B - q_B \right) \right) \\ &= 0. \end{aligned}$$

The inequality follows from $\delta < 1$ and $q'_B < q_B$, and the last equality follows from (12). This means that no user will switch from provider B to A after introducing the special content.

On the other hand, some original subscribers of provider A might want to switch to provider B due to the special content. However, these users will incur a switching cost z as they break the original contract.[4] Then a user will only switch from provider A to provider B if his utility improves after the switching, *i.e.*,

$$\theta(q_s + \sum_{t=2}^{T} \delta^{t-1} q'_B) - p_B \cdot T - z \geq \theta \sum_{t=1}^{T} \delta^{t-1} q_A - p_A \cdot T. \tag{13}$$

Let

$$Q(\delta) = (q_s + \sum_{t=2}^{T} \delta^{t-1} q'_B) - \sum_{t=1}^{T} \delta^{t-1} q_A.$$

Then (13) is equivalent to

$$\theta \cdot Q(\delta) \geq z - (p_A - p_B) \cdot T. \tag{14}$$

Function $Q(\delta)$ is a strictly decreasing in δ. It is positive when δ is close to 0 and negative when δ is close to 1. We can denote δ^{th} as the unique value such that $Q(\delta^{th}) = 0$.

[4] In a more general model, different users might have different switching costs, depending on when they signed the contract with their existing provider.

Next, we will discuss three cases based on the switching cost z.

Scenario 1. *Large switching cost:* $z > (p_A - p_B)T$.

In this case, users have to pay a high switching cost to switch. Users who are indifferent in terms of switching to provider B or stay with provider A have a parameter $\theta_{large}(\delta)$ that satisfies

$$\theta_{large}(\delta) = \frac{z - (p_A - p_B)T}{Q(\delta)}, \quad \forall \delta < \delta^{th}, \tag{15}$$

which is shown in Fig. 7. Here we need to have $\delta < \delta^{th}$ (*i.e.*, $Q(\delta) > 0$), otherwise no user will switch from A to B. Users with parameter (θ, δ) on the left hand side of the boundary will choose provider B. In fact, all users who are below curve $\theta^*(\delta)$ choose provider B even without the special content. Only users who are above the curve $\theta^*(\delta)$ and on the left of curve $\theta_{large}(\delta)$ are the switching users. We further notice that the threshold $\theta_{large}(\delta)$ increases with δ. This means that when δ increases, users need to have a larger evaluation θ in order to switch to provider B. Users on the right hand side of boundary $\theta_{large}(\delta)$ will stick to the original providers (either A or B).

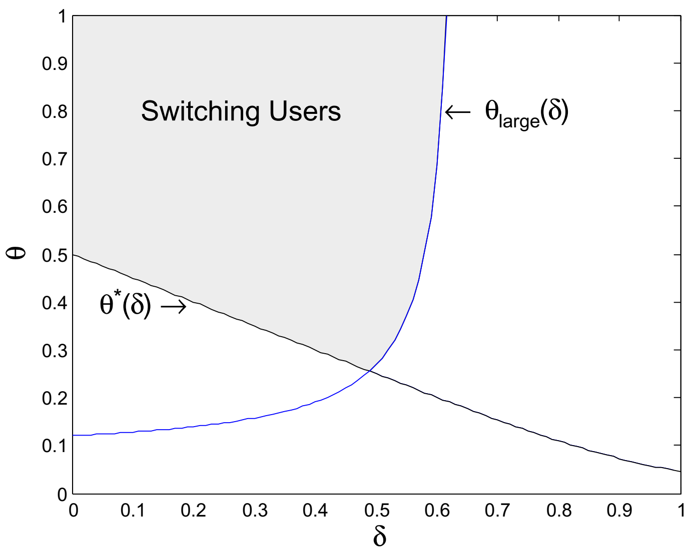

Fig. 7. Switching users under the high switching cost

Scenario 2. *Intermediate Switching Cost:* $z = (p_A - p_B)T$

In this case, users originally with provider A will switch to provider B if

$$\theta \cdot Q(\delta) \geq 0. \tag{16}$$

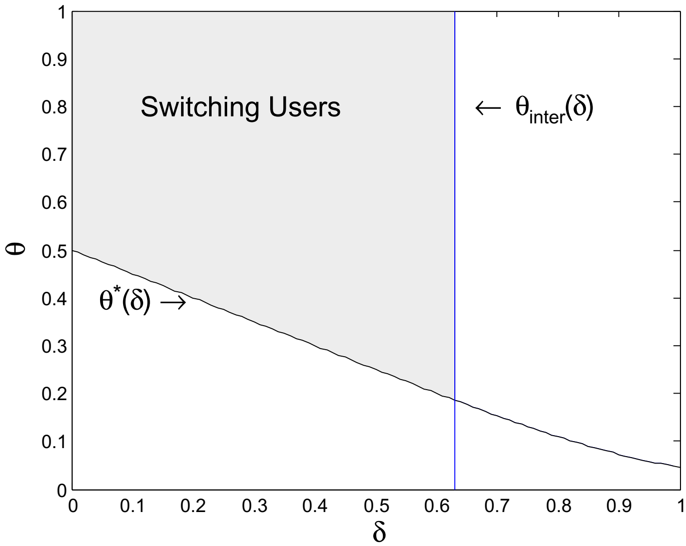

Fig. 8. Intermediate Switching Cost

The boundary value of θ is illustrated in Fig. 8, where all users with a $\delta \leq \delta^{th}$ will choose provider B, and all users with a $\delta > \delta^{th}$ will stick with their original choices. The boundary only depends on δ and is independent of the value of θ.

Scenario 3. *Small Switching Cost:* $0 \leq z < (p_A - p_B)T$.

In this case, users only need to pay a small switching cost. All users who have a $\delta < \delta^{th}$ will definitely choose provider B independent of θ. For users with a $\delta > \delta^{th}$ (*i.e.*, $Q(\delta) < 0$), the total content quality of provider B is less than A even after the introduction of special content. However, some users may still choose to switch from provider A to B, if the switch can bring significant reduction in terms of subscription fees (*i.e.*, $(p_A - p_B)T$). Thus the boundary value of θ can be characterized as

$$\theta_{small}(\delta) = \frac{z - (p_A - p_B)T}{Q}, \quad \forall \delta > \delta^{th}, \tag{17}$$

which is shown in Fig. 9. All users below the boundary and above the curve $\theta^*(\delta)$ will switch from provider A to B. Users who are under the curve $\theta^*(\delta)$ always stay with provider B. Notice that the boundary $\theta_{small}(\delta)$ actually decreases with θ.

The above three scenarios illustrate the importance of special content. When the switching cost z is large, only users with high valuations of the current content and content qualities (*i.e.*, small δ and large θ) will switch from provider A to B. As the switching cost decreases, the switching threshold moves towards the right and more users want to switch. This means that the provider B's revenue will increase due to more coverage and provider A's revenue will decrease.

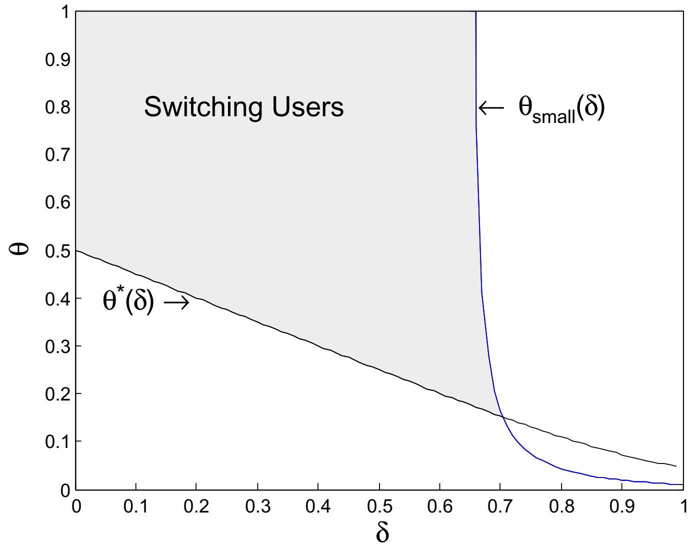

Fig. 9. Small Switching Cost

5 Conclusion and Future Work

Both content quality and market coverage have significant impacts on a network content provider's revenue. In this paper, we present a preliminary study on how providers' cooperation and adoption of special content can affect providers' content quality and change the market coverage. We first consider a baseline case, where providers have static content and do not cooperate. In this case, we derive the coverage of the providers based on the quality of the contents and user subscription fees. Then we consider how cooperation and content sharing can help providers to improve their revenues. The key insight is that cooperation will be desirable when the providers' total revenue is increased and properly shared by inter-provider financial transfers. In the case of linear advertisement functions, cooperation will happen when providers have different abilities in generating advertisement revenue and set subscription fees properly. We further consider the dynamic content case, where a provider can introduce some high quality special content for a short amount of time to attract users. We show that the switching cost, the valuation of content, and time discount factor all play important roles in deciding the benefit of special content.

There are several ways to extend this work. One direction is to consider the case where both providers can purchase special contents, and then it is possible for a user to switch more than once during T time slots. The two providers will engage in a game theoretical interaction in terms of the timing, quality, and length of the special contents. The other direction is to consider the strategic interactions between advertisers and content providers, *e.g.*, when an advertiser has the choice to work with more than one content provider to maximize its revenue. Finally, we will consider how providers can jointly optimize the subscription fees with the contents to become more competitive in the market.

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