

ISP and CP Revenue Sharing and Content Piracy

[Extended Abstract]

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ABSTRACT

With the network neutrality debate, the revenue sharing between Internet service providers (ISPs) and content providers (CPs) has been received attentions. In this paper, we study the revenue sharing of them from the perspective of collaboration to reduce online content piracy. With higher efforts of ISPs to reduce illegal content traffics, CPs have higher incentives to share their revenue with ISPs. We study the possibilities of such collaboration with a game theoretic model. Our preliminary results seem promising as both ISPs and CPs can be benefited from the cooperation.

Categories and Subject Descriptors

C.2.1 [Network Architecture and Design]: Wireless Communication

Keywords

Internet service provider, Content provider, Profit sharing, Contents piracy

1. INTRODUCTION

Internet traffic increases rapidly due to changes of traffic nature from text to video or audio contents. The increase in traffic puts a burden on Internet service providers (ISPs) as they are expected to invest more on the network infrastructures. However, the revenues of ISPs stagnate, causing network neutrality debates for last several years [1]. Another important issue over the Internet is the content piracy [2, 3, 4]. It is estimated that the percentage of traffic from illegal contents is as large as 23.8% of total global traffic [6]. Technologies such as P2P provides an easy environment for users to exchange content at their finger tips. In this paper, we explore the possibilities of profit sharing between ISPs and CPs by means of provisioning content protection. As the ISPs are able to monitor and control illegal contents sharing through networks, they can help CPs by actively putting efforts on cutting illegal content traffics, which in turn would improve financial situation of CPs. If the CPs could share some portion of their

profit, which could be a win-win strategy for both. We develop a mathematical model to understand behaviors and characterize the optimal strategies of ISPs and CPs. For further study, we show the behaviors of the two numerically.

2. SYSTEM MODEL

We consider an Internet ecosystem that consists of an ISP, a CP and a set of users with size of N .

2.1 User's utility

The CP provides contents to users through the network at the price of p_c . We assume that users' content valuations are heterogeneous and a user of type v has the net-utility u_v . Without loss of generality, we assume that v is distributed between 0 and \bar{v} with distribution function $F(v)$. The content is also available through illegal piracy such as p2p file sharing services and so on. However, an illegal content has a quality degradation α ($0 \leq \alpha \leq 1$)¹. As the acquisition of an illegal copy comes with a cost of β , the net-utility of a type v user can be written as follows:

$$u_v = \begin{cases} v - p_c, & \text{if a user purchases a legal one;} \\ (1 - \alpha)v - \beta, & \text{if a user copy an illegal one;} \\ 0, & \text{if a user does nothing.} \end{cases} \quad (1)$$

A type v user buys a legal content when

$$v - p_c \geq (1 - \alpha)v - \beta \text{ and } v - p_c \geq 0.$$

or

$$v \geq v_0 := \max \left[\frac{p_c - \beta}{\alpha}, p_c \right].$$

Therefore, the demand d_c for the legal contents is

$$d_c = M \cdot (1 - F(v_0)), \quad (2)$$

where M is the population of users who are interested in contents among ISP customers of size N ($\geq M$).

2.2 ISP's cooperation for anti-piracy

The ISP plays the role of a gate-keeper and is able to play the role of blocking specific content-sharing traffics, if he is willing to. If there were no legal or ethical issues, the ISP can play significant role in preventing

¹We adopted the model of [5] for the user utility.

users from distributing illegal contents over the Internet. Technology such as the deep packet inspection can be used for this objectives. In our work, we assume that the ISP can control the cost β of piracy. Hence, it can influence the behavior of users. However, it incurs cost $c_m(\beta)$, which is a nondecreasing function of β . Increasing β also has side effect of decreasing total number of ISP customers. The demand for internet access d_I is modeled as a decreasing function of β :

$$d_I = N(1 - a\beta), \quad (3)$$

where a is a nonnegative constant.

2.3 Profit sharing between ISP and CP

As the competition in the ISP market increases, most ISPs are looking for new revenue sources. There has been debate between ISPs and CPs regarding profit sharing. In our work, we consider sharing of contents revenue between ISPs and CPs, as ISP can play vital role in increasing CP's revenue by monitoring and controlling illegal content traffics. We would like to analyze the fair sharing portion between them and the monitoring impacts on user surplus and piracy rate. Let γ be the agreed revenue sharing fraction between the CP and the ISP, then the revenue π_{isp} of the ISP is given by:

$$\pi_{isp}(\beta; p_c) = d_I a_I + d_c a_c + \gamma d_c p_c - c_m(\beta), \quad (4)$$

where a_I is the flat fee from users and a_c is the charge from the CP per unit traffic for providing an Internet access service. The first term $d_I a_I$ is the revenue for access charges from users and the second term $d_c a_c$ is the access charge from the CP. We assume that the traffic generated is proportional to the demand d_c . The third term is the ISP's share of the CP's revenue and the last term is an inspection cost of ISP. The revenue π_{cp} is given by:

$$\pi_{cp}(p_c; \beta) = (1 - \gamma)d_c p_c - d_c a_c, \quad (5)$$

where the first term is the revenue from contents after giving a fraction $\gamma d_c p_c$ to the ISP and the second term is access charge to the ISP.

2.4 Sequential Model

We consider a game between the ISP and the CP, where ISP's strategy is controlling inspection parameter β while that of the CP is controlling price p_c of contents. With higher β , the ISP can increase legal content demand at the cost c_m of the ISP. The two players need to negotiate profit sharing fraction γ . Given profit sharing parameter γ , the ISP can determine optimal β that can maximize its revenue π_{isp} . Similarly, given γ , the CP can determine p_c that maximizes its own revenue π_{cp} .

The sequence of the game is :

1. The ISP and the CP negotiate profit sharing rate γ .
2. Given γ , the ISP and the CP determine traffic monitoring rate β and content price p_c , simultaneously.

In the second stage, the ISP and the CP determine β and p_c simultaneously as π_{isp} and π_{cp} are functions of

the two parameters for a given γ . We assume that two players play a simultaneous game to determine β and p_c .

3. ANALYSIS

3.1 No sharing case ($\gamma = 0$)

We first consider the no sharing case when $\gamma = 0$ as it is the current situation between the ISP and the CP. In the case of no sharing, the ISP's revenue is

$$\pi_{isp}(\beta; p_c) = d_I a_I + d_c a_c - c_m(\beta). \quad (6)$$

The second term $d_c a_c$ representing the increasing revenue from CP side even when $\gamma = 0$. From the first order condition, we have

$$-Naa_I + d'_c a_c = c'_m(\beta),$$

where $d'_c = \begin{cases} \frac{M}{\alpha \bar{v}}, & \text{if } \beta < p_c(1 - \alpha); \\ 0, & \text{if } \beta > p_c(1 - \alpha). \end{cases}$

Proposition 1. *Given price p_c for legal content, the optimal monitoring level $\beta^*(p_c)$ of the ISP under a no profit sharing condition ($\gamma = 0$) is:*

$$\beta^*(p_c) = \begin{cases} \min \left[c_m'^{-1}(\Delta_0), p_c(1 - \alpha) \right], & \text{if } \Delta_0 \geq 0; \\ 0, & \text{otherwise,} \end{cases} \quad (7)$$

where $\Delta_0 = \frac{M}{\alpha \bar{v}} a_c - Naa_I$.

Proposition 1 says that optimal monitoring level $\beta^* = 0$ when the loss Naa_I due to leaving user is higher than the revenue from the CP side access fee $\frac{M}{\alpha \bar{v}} a_c$. However, the ISP has an incentive to perform monitoring action, otherwise. As higher monitoring can increase the CP side access revenue, ISP's action depends on the magnitude of the two. Note that the optimal monitoring level is bounded by $p_c(1 - \alpha)$, which is the utility of the illegal content. If c_m is a nondecreasing convex function, there exists an optimal β^* that satisfies equation(7). The best strategy of the CP is determined to maximize its profit function

$$\pi_{cp}(p_c) = (p_c - a_c) \cdot d_c, \quad (8)$$

From equation (2), we have

$$\begin{cases} \pi_{cp}^1(p_c) = (p_c - a_c)M(1 - \frac{p_c}{\bar{v}}), & \text{if } p_c \leq \frac{\beta}{(1-\alpha)}; \\ \pi_{cp}^2(p_c) = (p_c - a_c)M(1 - \frac{p_c - \beta}{\alpha \bar{v}}), & \text{otherwise.} \end{cases}$$

Proposition 2. *Given monitoring level β of the ISP, the optimal content price $p_c^*(\beta)$ of the CP under the no profit sharing condition ($\gamma = 0$) is one among $\{p_c^{1*}, p_c^{2*}, p_c^M\}$, where*

$$p_c^{1*} = \frac{\bar{v} + a_c}{2}, p_c^{2*} = \frac{\alpha \bar{v} + \beta + a_c}{2}, \text{ and } p_c^M = \frac{\beta}{1 - \alpha}.$$

Note that p_c^{1*} is the maximizer of π_{cp}^1 and p_c^{2*} is that of π_{cp}^2 when there are no restrictions on the range of p_c . As the two functions have restrictions, there are four possible cases depending on whether $p_c^{i*} \leq p_c^M$ or not for $i=1,2$ as shown in table1. $\pi_{cp}(p_c^{i*})$ for $i=1,2$ need to be compared to determine optimal strategy.

Table 1: optimal p_c^* of the four cases

	$p_c^{2*} \leq p_c^M$	$p_c^{2*} > p_c^M$
$p_c^{1*} \leq p_c^M$	case I: p_c^{1*}	case III: p_c^{1*} or p_c^{2*}
$p_c^{1*} > p_c^M$	case II: p_c^M	case IV: p_c^{2*}

3.2 Sharing case ($\gamma > 0$)

When the CP agrees to share its profit by providing $\gamma d_c p_c > 0$, the revenue of the ISP in (4) has additional term of $\gamma d_c p_c$ than in (6). Also, the CP's revenue in (5) is decreased by the same amount. Proposition 3 is optimal strategy β^* of the ISP under the profit sharing condition. The ISP maintains a higher monitoring level β^* than under the no sharing condition.

Proposition 3. *Given price p_c for content, the optimal monitoring level $\beta^*(p_c)$ of the ISP under a profit sharing condition of $\gamma(> 0)$ is:*

$$\beta^*(p_c) = \begin{cases} \min [c_m'^{-1}(\Delta_1), p_c(1 - \alpha)], & \text{if } \Delta_1 \geq 0; \\ 0, & \text{otherwise,} \end{cases} \quad (9)$$

where $\Delta_1 = \frac{M}{\alpha \bar{v}}(a_c + \gamma p_c) - N a a_I$.

Proposition 4 shows the best response p_c^* of the CP under profit sharing condition.

Proposition 4. *Given monitoring level β of the ISP, the optimal content price $p_c^*(\beta)$ of the CP under the profit sharing condition $\gamma(> 0)$ is one among $\{p_c^{1**}, p_c^{2**}, p_c^M\}$, where*

$$p_c^{1**} = \frac{\bar{v}}{2} + \frac{a_c}{2(1 - \gamma)}, p_c^{2**} = \frac{\alpha \bar{v} + \beta}{2} + \frac{a_c}{2(1 - \gamma)}$$

and

$$p_c^M = \frac{\beta}{1 - \alpha}.$$

4. NUMERICAL RESULTS

Simulation Parameters: We perform a numerical analysis of our model with parameters of Table 2 for easy understanding. We assume the percentage of population who use the content service is a half of the total Internet users by setting $\frac{M}{N} = \frac{1}{2}$. The user access charge a_I is 0.5. Similarly, the content access charge $a_c = 0.5$. We change the revenue sharing ratio of the CP to be variable from 0% to 50% with an increment of 10%. The content quality degradation parameter α is 0.2. We assume that $c_m(\beta) = \frac{N}{10}\beta^2$. Then, $c_m'^{-1}(a) = \frac{5a}{N}$.

Best Responses and Nash Equilibrium: The optimal β^* of (9) reduces to

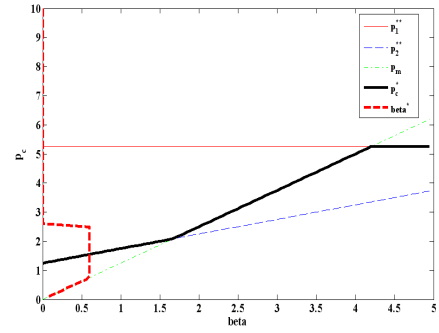
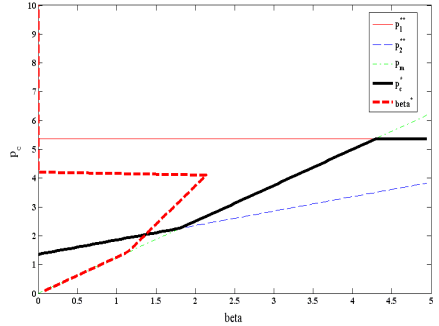
$$\beta^*(p_c) = \min \left[\frac{M}{N} \frac{(a_c + \gamma p_c)}{\alpha \bar{v}} - a a_I, p_c(1 - \alpha) \right].$$

In Figure 1, the thick dashed vertical line corresponds to β^* . When content price p_c is small, β^* is bounded by $p_c(1 - \alpha)$ and increases rather faster. However, after reaching $\frac{M}{N}(a_c + \gamma p_c) - a a_I$, the value is fixed when $\gamma = 0$ until Δ_1 is positive. When $\gamma = 0.3$ in Figure

Table 2: Simulation Parameters

symbol	meaning	value
N	population of Internet users	2
M	population of contents users	1
a_I	flat user access charge	0.5
a_c	CP access charge per traffic	0.5
γ	profit sharing ratio	variable
α	content quality degradation rate	0.2
β	monitoring effort of the ISP	variable
a	network user leaving rate with β	0.01
\bar{v}	maximum willingness to pay	10

2, β^* increases with p_c rather slowly after reaching the point while Δ_1 is positive.


Figure 1: Best Responses β^* and $p_c^*(\gamma = 0)$

Figure 2: Best Responses β^* and $p_c^*(\gamma = 0.3)$

The optimal pricing strategy candidates of the CP from proposition 4 reduce to:

$$p_c^{1**} = \frac{10}{2} + \frac{1}{4(1 - \gamma)}, p_c^{2**} = \frac{2 + \beta}{2} + \frac{1}{4(1 - \gamma)}$$

and

$$p_c^M = \frac{\beta}{0.8},$$

which are shown in Figure 1 and 2, respectively. Note that the best response p_c^* consists of three parts: the first part corresponds to the case IV ($p_c^* = p_c^{2**}$). The

second part corresponds to the case II ($p_c^* = p_c^M$). The last part corresponds to the case I ($p_c^* = p_c^{1**}$).

Note also that there exists a unique Nash equilibrium in both figures, which is crossing point of two best responses². When $\gamma = 0$, the Nash equilibrium is $(\beta, p_c) = (0.60, 1.53)$. When $\gamma = 0.3$, the Nash equilibrium becomes $(\beta, p_c) = (1.35, 2.02)$. With profit sharing, we can see that the content price p_c tends to increase and so does the monitoring level β .

Impact of profit sharing ratio: Table 3 shows the summary of the numerical study with the given parameters. We can make the following observations from

Table 3: Simulation Results

γ	0	10%	20%	30%	40%	50%
β^*	0.60	0.81	1.05	1.35	1.75	2.40
p_c^*	1.53	1.69	1.82	2.02	2.30	3.00
π_{isp}	1.19	1.24	1.30	1.36	1.40	1.22
π_{cp}	0.55	0.57	0.59	0.61	0.64	0.70
user surplus	0.37	0.35	0.34	0.32	0.30	0.25
piracy rate	0.39	0.33	0.25	0.16	0.06	0

Table3.

- The optimal monitoring level β^* tends to increase with a higher profit sharing parameter γ from 0.6 to 2.4, which is expected because the ISP could gain more from the CP's revenue. As the ISP could gain more from the decrease of content piracy, the ISP has a higher incentive to put efforts on monitoring.
- Similarly, the content charge tends to increase with a higher revenue sharing parameter from 1.53 to 3.00. As the CP does not need to worry as much about content piracy as before, it can increase the price level p_c .
- Both the revenue of the ISP and that of the CP increase with the revenue sharing. The revenue of the ISP increases from 1.19 ($\gamma = 0\%$) to 1.40 ($\gamma = 40\%$) and then decreases a bit at 50% to 1.22. We think that the decrease in the last part comes from increasing convex monitoring cost. The revenue of CP increases even though that a large fraction of the revenue is shared with the ISP. This can be explained from the increase of the legal content market. As many users who uses illegal content join the legitimate content market, the total market size increases.
- The user surplus decreases from 0.37 to 0.25. The user surplus include that of legal and illegal content users. As the price of the content increases, it is expected outcome. A more careful analysis is needed to understand this aspect so that the reduction of the user surplus is marginal from the regulator's perspective.

²The uniqueness of a Nash equilibrium does not always hold. We are currently investigating the conditions of Nash points.

5. CONCLUSIONS AND FUTURE WORK

In this paper, we considered a possibility of revenue sharing between ISPs and CPs based on collaboration of the two to reduce online content piracy. Additional efforts of ISPs to reduce illegal content deliveries over the Internet, CPs could have incentives to share their revenues with ISPs for their work on piracy removal. To understand the behaviors, we developed a simple mathematical model consisting of an ISP, a CP and a group of users. We characterized the optimal behaviors of the participants and performed a numerical study. The numerical results are promising as they showed decreasing piracy rate, increasing revenues of the ISP and that of the CP, which improve the hope for revenue sharing. However, the decreasing user surplus requires more attention and additional future work. Though our work is the first trial to study the effectiveness of ISP-CP cooperation on contents piracy with a game model, we cannot deny that our work is limiting in many aspects: characterization of Nash equilibrium, more realistic parameters, impact of reducing network congestion as piracy traffics go down, which will be our further study topic.

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