Feasibility Analysis of Content Charge by ISPs

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Content

• Introduction

• Model

• Optimum strategies of CPs

• Optimum strategies of ISP-1

• Conclusion
- **Problem**
  - ISP invests the network infrastructure to maintain QoS.
  - ISP covers investment cost by charging content delivery to CPs.
  - CPs can switch to other ISPs

→ charging contents delivery may not effective for ISPs
Feasibility Analysis of Content Charge by ISPs

• Research question
  
  What happen in Internet Ecosystem with ISPs that one introduces the content charge to CPs and others don’t?

• Contribution
  – First trial study that finding conditions for achieving content charging and effect on the ISPs
  – Referring to “ISP vs. ISP+CDN : Can ISPs in duopoly profit by introducing CDN Services?” and “ISP and CP revenue sharing and Content piracy”
Stackelberg Game

• Game design
  Players       ISP-1 and CPs
  ISP-1        Content charging ($\alpha$)
  CPs          strategy with different set of ISPs ($k$)

• Game sequence
  1$^{st}$ stage  Determination of content charging by ISP-1
  2$^{nd}$ stage Determination the entering set of ISPs($k$) by CPs
Model

• **Structure**

Players
- Two types of users, Two types of ISPs and N number of CPs

Assumptions
- No transit fee between two ISPs
- Fixed number of users
Profit function of CPs

- Strategy of CP-x with k strategy as connect to no ISP (K=0), ISP-1(K=1), ISP-2(K=2) and both ISPs(k=3)

- Monthly revenue of CPs using k strategies ($\phi_{x,k}$)

$$\phi_{x,k} = \text{profit - transit fee - leased line fee}$$

$$\phi_{x,0} = 0$$

$$\phi_{x,1} = \frac{P(1-\alpha)z_x(u_1 + \gamma u_2)}{\text{price}} - n_tz_x^\beta(u_1 + \gamma u_2)^\beta - F$$

- Total amount of requested content
- Constant $\beta$

$$\phi_{x,2} = Pz_x(y u_1 + u_2) - n_tz_x^\beta(y u_1 + u_2)^\beta - F$$

- Quality degradation through both ISPs

$$\phi_{x,3} = Pz_x{(1 - \alpha)u_1 + u_2} - n_tz_x^\beta{(u_1^\beta + u_2^\beta)} - 2F$$

- Coefficient of transit fee

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<th>Symbol</th>
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<td>$\alpha$</td>
<td>Content delivery charging by ISP-1</td>
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<td>$z_x$</td>
<td>Requested traffic to CP-x</td>
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<td>$u_i$</td>
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**Optimum Strategy of CPs**

- **Theorem 1**

  The CP set of each strategy, $H_0, H_1, H_2$ and $H_3$ is obtained by

  $H_0 = H \setminus \{H_1 \cup H_2 \cup H_3\}$

  $H_1 = \{x \in A_1: \alpha \leq \min(\rho_{x,b}, \sigma_{x,a})\} \cup \{x \in A_2: \alpha \leq \min(\rho_{x,a}, \sigma_{x,a})\}$

  $H_2 = \{x \in A_1: \alpha \geq \max(\rho_{x,c}, \sigma_{x,b}), \phi_{x,2} > 0\} \cup \{x \in A_2: \alpha \geq \rho_{x,a}, \phi_{x,2} > 0\}$

  $H_3 = \{x \in A_1: \rho_{x,b} < \alpha < \min(\rho_{x,c}, \sigma_{x,b})\}$.

  ![Diagram](image.png)

  \[\phi_{x,1} = P(1 - \alpha)z_x(u_1 + \gamma u_2) - n_z^\beta(u_1 + \gamma u_2)^\beta - F\]

  \[\phi_{x,2} = Pz_x(\gamma u_1 + u_2) - n_z^\beta(\gamma u_1 + u_2)^\beta - F\]

  \[\phi_{x,3} = Pz_x((1 - \alpha)u_1 + u_2) - n_z^\beta(u_1^\beta + u_2^\beta) - 2F\]
Optimum strategies of ISP-1

• Monthly revenue ($R_1$)

$$R_1 = \sum_{x \in H_1} \left\{ (\alpha P - G)z_x (u_1 + \gamma u_2) + n_t z_x^\beta (u_1 + \gamma u_2)^\beta \right\}$$

Contents revenue Transit fee

$$- \sum_{x \in H_2} Gz_x \gamma u_1$$

Contents revenue

$$+ \sum_{x \in H_3} \left\{ (\alpha P - G)z_x u_1 + n_t z_x^\beta u_1^\beta \right\}$$

Contents revenue Transit fee

Symbol | Meaning
--- | ---
$P$ | Content price
$\alpha$ | Content delivery charging by ISP-1
$G$ | Cost of delivering content
$z_x$ | Requested traffic to CP-x
$u_i$ | Number of user of ISP-i
$\gamma$ | Quality degradation through both ISPs
$n_t$ | Coefficient of transit fee
$\beta$ | Parameter of transit fee (fixed value)

• Theorem 2

It is sufficient for ISP-1 to consider only $\alpha \in M$ as the candidate for the setting value of $\alpha$, and ISP-1 can maximize $R_1$ when setting $\alpha$ to each member of $M$ and selecting $\alpha$ that maximizes $R_1$ as the optimum value of $\alpha$, $\alpha^*$. $M$ is $M_1 \cup M_2 \cup M_3 \cup M_4 \cup M_5$ such that

$M_1 \equiv \{ \rho_{x,b}, \rho_{x,c} : x \in A_1 \}$,

$M_2 \equiv \{ \sigma_{x,a} : x \in A_1, \sigma_{x,a} < \rho_{x,b} \}$,

$M_3 \equiv \{ \sigma_{x,b} : x \in A_1, \sigma_{x,b} < \rho_{x,c} \}$,

$M_4 \equiv \{ \rho_{x,a} : x \in A_2 \}$,

$M_5 \equiv \{ \sigma_{x,a} : x \in A_2, \sigma_{x,a} < \rho_{x,a} \}$
Conclusion

• Existence of optimum strategies of CP
  – Selecting the ISPs with charging price or not
  – Maximizing CP-x’s profit

• Existence of optimum charging of ISP-1
  – Selecting the optimal charging price that maximizes ISP-1s profit
Thank you