Effects of Sponsored Data Plans

Shivam Garg (12D020036)
Anant Gupta (120050086)
Pranjal Batra (121030031)

EE 758 - Internet Economics
IIT Bombay

5 April 2016

Overview

Introduction to Sponsored Data

Data Sponsoring

A pricing model in which content providers have the option to pay partially or fully for the content consumed by the end users.

Introduction to Sponsored Data

- Google has joined with Bharti Airtel to offer free access to certain Google-based services such as Gmail and Google+ in India.

Introduction to Sponsored Data

- Google has joined with Bharti Airtel to offer free access to certain Google-based services such as Gmail and Google+ in India.
- End users can access more content!
- Content providers will get more views!
- ISPs can get higher revenue by charging content providers more for the sponsored data!

Introduction to Sponsored Data

- A win-win situation for all?

Introduction to Sponsored Data

- A win-win situation for all?
- Not necessarily!

Sponsored Data Plan: A Two-Class Service Model

Zhang, Wu, Wang

- Discusses the impact of sponsored data plan on end users, CPs and ISPs.

Model

- Number of CPs: N
- Number of ISP: 1
- Number of end users: M
- Traffic capacity of the ISP: μ

Model

Consumer's Traffic Demand

- Strictly decreasing utility density function: $g_i(x_i) = \alpha_i e^{-\beta_i x_i}$

Model

Consumer's Traffic Demand

- Strictly decreasing utility density function: $g_i(x_i) = \alpha_i e^{-\beta_i x_i}$
- QoS for service i: $q_i \in [0, 1]$
- QoS satisfaction function: $h_i(q_i) = q_i^{\gamma_i}$

Model

Consumer's Traffic Demand

- Strictly decreasing utility density function: $g_i(x_i) = \alpha_i e^{-\beta_i x_i}$
- QoS for service i: $q_i \in [0, 1]$
- QoS satisfaction function: $h_i(q_i) = q_i^{\gamma_i}$
- Total utility for consuming x_i amount of traffic: $\int_0^{x_i} g_i(s) h_i(q_i) ds$

Model

Consumer's Traffic Demand

- Strictly decreasing utility density function: $g_i(x_i) = \alpha_i e^{-\beta_i x_i}$
- QoS for service i: $q_i \in [0, 1]$
- QoS satisfaction function: $h_i(q_i) = q_i^{\gamma_i}$
- Total utility for consuming x_i amount of traffic: $\int_0^{x_i} g_i(s)h_i(q_i)ds$
- User consumes traffic from service i, iff marginal utility $\geq t_i$
- Usage threshold: $\theta_i = max\{s : g_i(s)h_i(q_i) \geq t_i\}$

Model

Consumer's Traffic Demand

- Strictly decreasing utility density function: $g_i(x_i) = \alpha_i e^{-\beta_i x_i}$
- QoS for service i: $q_i \in [0, 1]$
- QoS satisfaction function: $h_i(q_i) = q_i^{\gamma_i}$
- Total utility for consuming x_i amount of traffic: $\int_0^{x_i} g_i(s)h_i(q_i)ds$
- User consumes traffic from service i, iff marginal utility $\geq t_i$
- Usage threshold: $\theta_i = max\{s : g_i(s)h_i(q_i) \geq t_i\}$
- Total surplus of consuming x_i units of service i: $\int_0^{x_i} [g_i(s)h_i(q_i) - t_i]ds$

Model

- ISP applies flat pricing scheme with a cap C
- Two set of CPs:
  - $\mathcal{O}$: Contains ordinary CPs (No sponsoring)
  - $\mathcal{S}$: Contains CPs who sponsor completely

Model

User Optimization Problem

$$\max_{x} \sum_{i\in\mathcal{N}} \int_{0}^{x_i} [g_i(s)h_i(q_i) - t_i]ds$$
$$\text{s.t.} \quad \sum_{i\in\mathcal{O}} x_i \leq C, 0 \leq x_i \leq \theta.$$

Solution

$$x_i = \begin{cases} \max\{0, g_i^{-1}(\frac{t_i+\nu}{h_i(q_i)})\}, & i \in \mathcal{O}, \\ \theta_i, & i \in \mathcal{S} \end{cases}$$

Model

Solution

$$x_i = \begin{cases} \max\{0, g_i^{-1}(\frac{t_i+\nu}{h_i(q_i)})\}, & i \in \mathcal{O}, \\ \theta_i, & i \in \mathcal{S} \end{cases}$$

- ν interpreted as the level of competition among CPs.
- Large $C \Rightarrow$ Traffic usage of services in $\mathcal{O}$ approach usage threshold.

Model

Capacity Sufficiency

- ISP's capacity μ is sufficient, if the total data consumption $D(q) \leq \mu$ when quality of service $q = 1$.
- If $D(1) < \mu$, ISP operates at equilibrium QoS $q < 1$ such that $D(q) = \mu$.
- Average capacity per user: $\lambda = \mu/M$.
- Equilibrium QoS q increases with μ.

Model

Utility of CPs

- Utility of CP i,

$$\phi_i(c_i, p) = \begin{cases} (v_i - c_i)x_i(q), & i \in \mathcal{O}, \\ (v_i - c_i - p)\theta_i(q), & i \in \mathcal{S} \end{cases}$$

where CP pays c_i to ISP per unit data,
and p is the sponsoring price per unit data

Utility of ISP

Utility of ISP, denoted by π is:

$$\pi(c_i, p) = \sum_{i \in \mathcal{S}} (c_i + p)\theta_i(q) + \sum_{i \in \mathcal{O}} c_i x_i(q)$$

.

Model

A Two Stage Stackelberg Game

- Players: CPs and ISP.
- Strategies:
  - ISP decides (p,C)
  - CPs decide whether to join ordinary class or sponsored class
- Rules:
  - ISP is the first mover who decides p and traffic cap C and announces them to CPs and users.
  - CPs are second movers and decide which class to join independent of each other.

Content Providers' Strategy

- At equilibrium, no content provider should be able to increase its utility by moving to the other class.

Content Providers' Strategy

- At equilibrium, no content provider should be able to increase its utility by moving to the other class.
- When the *ISP* capacity is sufficient, relative priority of CP_i is: $\rho_i = g_i((v_i - c_i - p)g_i^{-1}(t_i)/(v_i - c_i)) - t_i$
- Relative priority denotes the highest level of competition that CP_i can tolerate in the ordinary class.

Content Providers' Strategy

- At equilibrium, no content provider should be able to increase its utility by moving to the other class.
- When the *ISP* capacity is sufficient, relative priority of CP_i is: $\rho_i = g_i((v_i - c_i - p)g_i^{-1}(t_i)/(v_i - c_i)) - t_i$
- Relative priority denotes the highest level of competition that CP_i can tolerate in the ordinary class.
- If $\tilde{\nu}$ is the level of competition at equilibrium, then CP_i's choice is:

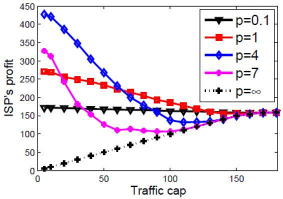
$$i \in \begin{cases} \mathcal{O}, & \rho_i \geq \tilde{\nu}, \\ \mathcal{S}, & \rho_i < \tilde{\nu} \end{cases}$$

Some Characteristics of the Outcome

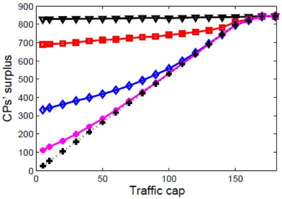
- If *ISP* increases user traffic cap C or sponsoring price p, it gives each *CP* a higher incentive to join the ordinary class.

Some Characteristics of the Outcome

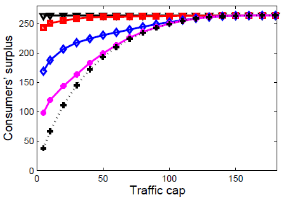
- If *ISP* increases user traffic cap C or sponsoring price p, it gives each *CP* a higher incentive to join the ordinary class.
- Those *CPs* having high per unit revenue or quality sensitivity usually have high incentive to join the sponsored class, and in turn make more revenue.



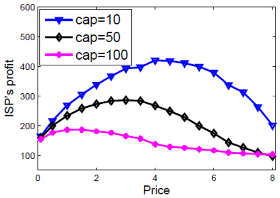
(a) π vs. traffic cap

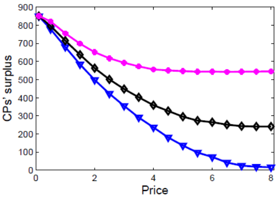


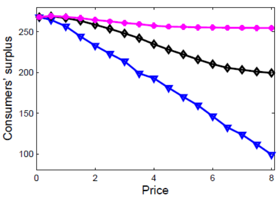
(b) ϕ vs. traffic cap



(c) ψ vs. traffic cap



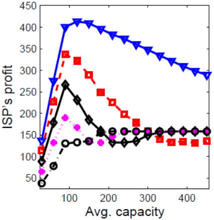




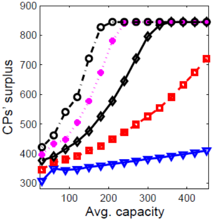
Some Observations

- When *ISP*s capacity is sufficient, *CP*s, *ISP* and users, all benefit from the sponsored data plan.
- No incentive for *ISP* to enlarge its traffic cap.
- Keeping a small user traffic cap and charging a high sponsoring price will bring in more revenue for the ISP.

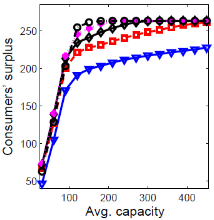
Insufficient Capacity



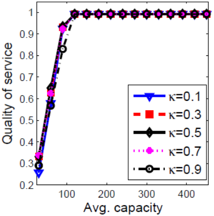
(a) π vs. capacity



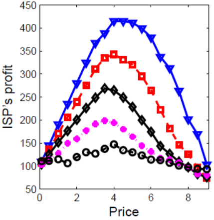
(b) ϕ vs. capacity



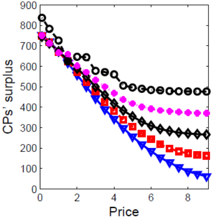
(c) ψ vs. capacity



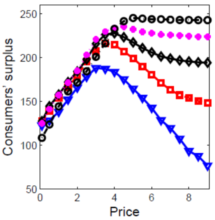
(d) q vs. capacity



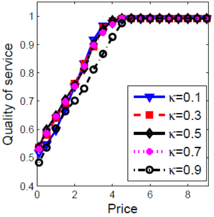
(a) π vs. price



(b) ϕ vs. price



(c) ψ vs. price



(d) q vs. price

Some Observations

- Note that the ISP has a strong incentive to enlarge its traffic capacity until the *QoS* become 1 which is beneficial for both *CP*s and users.
- A high sponsoring price *p* (upto a certain limit) is beneficial for both *ISP* and users but not favorable for *CP*s.
- Hence, in this case, end users always benefit from sponsored data while *ISP* and *CP*s compete for revenue.

Criticism

- The model assumes that a user can consume any amount of sponsored data which is not true due to limitation on available time.
- Different costs c_i for different CPs
- The model assumes a single ISP with fixed number of end users while in reality many ISPs compete to get end users.

Sponsoring Mobile Data: An Economic Analysis of the Impact on Users and Content Providers

Joe-Wong, Ha, Chiang

- Considers CPs choice of how much content to sponsor and the implications for users, CPs, and ISPs
- Reverses certain intuitions about user demand and utility change

Model

- CPs decide what and how much to sponsor
- Per-app proxies for sponsored traffic used by CPs
- ISPs can easily identify sponsored traffic

Model

2 types of CPs:

CP type	Benefit Source	Benefit from usage	Example
Revenue	Ad revenue	Linear in usage	Pandora
	Subscriptions	Linear in usage	Vimeo
	Subscriptions	Linear in # of users	Netflix
Promotion	Goodwill	Concave in usage	Promotions
	Usage	Concave in usage	Enterprise

Model

- *Single ISP*, N users, M CPs
- ISP sets price $\rightarrow$ CPs decide amount of sponsorship $\rightarrow$ users decide consumption
- User-CP interaction independent of other users and CPs

User's Problem

- User i consumes monthly content $x_{i,j}$ from CP j
- Ads per content s_j
- Data sponsored per content $\gamma_{i,j}$
- Cost $p_u(1 - \gamma_{i,j} + s_j)x_{i,j}$, where p_u is the unit data price
- Utility $U_{i,j}(x_{i,j}(1 + r_{i,j}s_j))$, where $r_{i,j}$ is the click-through rate

User's Problem

Therefore, user optimizes for $x_{i,j}$:

$$V_{i,j} = c_{i,j}\frac{(x_{i,j}(1 + r_{i,j}s_j))^{1-\alpha_{i,j}}}{1 - \alpha_{i,j}} - p_u(1 - \gamma_{i,j} + s_j)x_{i,j}$$

where we take $U_{i,j}(x) = c_{i,j}x^{1-\alpha_{i,j}}/(1 - \alpha_{i,j})$
This can be solved in closed form

CP's Problem

CP optimizes for $\gamma_{i,j}$:

$$W_{i,j}(\gamma_{i,j}) = \bar{U}_{i,j}(x^\star_{i,j}) - p_c \gamma_{i,j} x^\star_{i,j}$$

where:

- $\bar{U}_{i,j}(x) = d_{i,j} x^{1-\beta_{i,j}} / (1 - \beta_{i,j})$
- $x^\star$ is the user demand
- $p_c \gamma_{i,j} x^\star_{i,j}$ is the cost due to sponsorship of user i
- p_c is the cost per unit data

CP's Problem

Revenue CP

- Utility = Revenue
- Revenue proportional to user demand $\Rightarrow \beta_{i,j} = 0$
- $d_{i,j} = ar_{i,j}s_j$ where a is the revenue per ads clicked

Promotion CP

- Utility = Benefit directly from usage
- $\beta_{i,j} = \alpha_{i,j}$

ISP's Problem

- Maximum monthly demand for data, X
- User i's effective data price for CP j: $\pi^{\star}_{i,j}(p_c, p_u) = p_u(1 - \gamma^{\star}_{i,j}(p_c, p_u) + s_j)$
- CP j's effective data price for user i is: $p_c\gamma^{\star}_{i,j}$
- Data of user i for CP j over ISP's network: $(1 + s_j)x^{\star}_{i,j}$

ISP's Problem

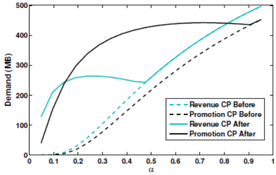
Therefore, the ISP optimizes for p_u and p_c:

$$\max_{p_c, p_u \geq 0} \sum_{i=1}^{N} \sum_{j=1}^{M} (\pi_{i,j}^{\star} + p_c \gamma_{i,j}^{\star}) x_{i,j}^{\star}(\pi_{i,j}^{\star})$$

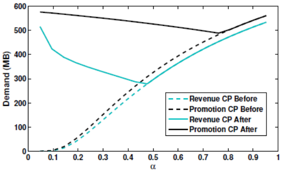
$$s.t. \sum_{i=1}^{N} \sum_{j=1}^{M} (1 + s_j) x_{i,j}^{\star}(\pi_{i,j}^{\star}) \leq X$$

User demand and price elasticity

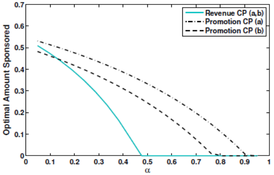
- User demand increases with increasing CP sponsorship
- Without sponsorship, user demand increases as price elasticity decreases
- With sponsorship, demand can both increase or decrease



(a) Non-monotonic user demand.



(b) Decreasing user demand.



(c) Optimal amounts sponsored.

Impact on Users and CPs

User utility and ads

- Without sponsorship, utility decreases as s_j increases
- With sponsorship, for revenue CPs, utility increases if $ar_{i,j} > p_c$ and $\gamma^{\star}_{i,j} > 0$.

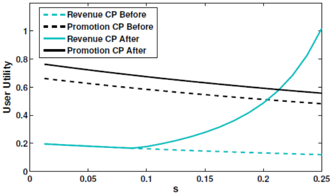


Figure: User utilities, varied s_j

Impact on Users and CPs

Fairness across price elasticity

- Consider a set S of users with different price elasticities $\alpha_{i,j}^{-1}$ and a CP j with same $d_{i,j}$ for all users
- Relative demand decreases as users become less price-elastic
- If user demands $x_{i,j}$ increase as price elasticities $\alpha_{i,j}^{-1}$ decrease, fairness increases

Impact on Users and CPs

Fairness across user cost awareness

- Consider a set of users who vary only in their cost awarenesses $c_{i,j}^{-1}$ and a CP j with the same $d_{i,j}$ for all users.
- For promotion CPs, users' relative demands and benefits increase with $c_{i,j}^{-1}$. Thus, user demands and utilities become fairer with sponsorship.
- For revenue CPs, relative demand and benefit is independent of cost awareness, so fairness does not change.

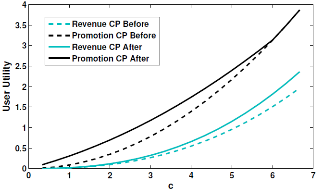


Figure: User utilities, varied $c_{i,j}$

Impact on Users and CPs

Fairness across CP cost awareness

- Consider a set of homogeneous users and a set of either revenue or promotion CPs varying only in their cost awareness $d_{i,j}^{-1}$.
- The demand and CP utility distributions become less fair with sponsorship.

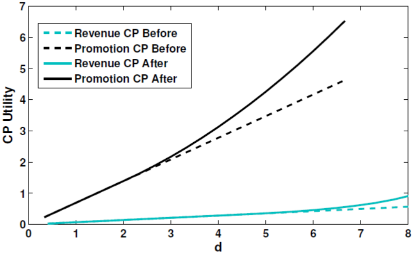


Figure: CP utilities, varied $d_{i,j}$

Impact on Users and CPs

Overall utility increase

- Suppose p_u doesn't increase after sponsorship
- Then utilities of users, CPs and ISP increase or remain the same

User vs CP utilities

- The ratio of CP to user utility is lower after sponsorship.
- The ratio increases as p_c increases.

Criticism

- No constraint on time in optimization problem for user
- No constraint on capacity of CPs
- No exchange between CP and ISP (except sponsorship)
- QoS not considered

A Different Model

- Previous Model assumes data limit on only non-sponsored groups while we should have a data limit on both (owing to limited time). The following model divides users in different user groups and constraints their usage irrespective of sponsorship
- Previous models omit the revenue by end users in ISP's optimization problem which is not the case in this model.

User Optimization Problem

- Users non decreasing valuation function $\psi(x)$
- Consumption of θ_{ij} data from CP i and user j has value $g_{ij}\psi(\theta_{ij})$
- Therefore the utility for user j by consuming θ_{ij} from CP i is $\sum_{i \in N} g_{ij}\psi(\theta_{ij}) - p\sum_{i \in O} \theta_{ij}$

User Optimization Problem

- Users non decreasing valuation function $\psi(x)$
- Consumption of θ_{ij} data from CP i and user j has value $g_{ij}\psi(\theta_{ij})$
- Therefore the utility for user j by consuming θ_{ij} from CP i is $\sum_{i\in N} g_{ij}\psi(\theta_{ij}) - p\sum_{i\in O}\theta_{ij}$
- The optimization problem each user group j can be framed as

$$\underset{x}{\text{minimize}} \quad -(\sum_{i\in N} g_{ij}\psi(\theta_{ij}) - p\sum_{i\in O}\theta_{ij})$$

$$\text{subject to} \quad \sum_{i\in N}\theta_{ij} - C_j \leq 0$$

$$\text{and} \quad -\theta_{ij} \leq 0$$

Hotelling model

- There are 2 hotels at the end points of a street.
- Users are uniformly distributed across the street.
- Users select one of the hotels based on the pricing and the distance they need to travel to reach the hotel.
- Similar concept can be used to model the case of 2 *ISP*s.

Two ISP's using Hotelling model

- Consider QoS as an analogue to distance in the hotelling model.
- Instead of all users being identical, we will have many groups of identical users.
- Each ISP offers a different *QoS* to different groups of people.
- It may be the case that Airtel network is better in Mumbai as compared to Srinagar while BSNL network is better in Srinagar.

Two ISP's using Hotelling model

- Consider a game in which both *ISP*s initially decide the following:
  1. q_i: Quality of service for user group i.
  2. C_i: Usage cap for user group i.
  3. $p_{u,i}$: Flat price charged to user group i.
  4. c_j: Price per units data charged to CP_j.
  5. p_c: Extra price per unit data charged to *CP*s in sponsored class.

Two ISP's using Hotelling model

- Based on this, *CPs* decide which *ISP* to join and whether to sponsor or not.
- The optimization problem for *CPs* will be same as before.
- After the decision of *CP*s and *ISP*s, end users decide how much data to consume and which *ISP* to join.
- The optimization problem for user group j will have an additional term for flat price in its surplus:

$$\max_{x} \quad \left(\sum_{i \in \mathcal{N}} \int_0^{x_i} [g_i(s) h_i(q_j) - t_i] ds\right) - p_{u,j}$$
$$\text{s.t.} \quad \sum_{i \in \mathcal{O}} x_i \le C_j, 0 \le x_i \le \theta.$$

- Each user will choose the *ISP* which maximizes its surplus.

Unified View

Differences between the two papers

- First paper considers QoS while the second one completely ignores it.
- No option of partially sponsoring the data in the first paper.
- Second paper distinguishes CPs based on their revenue sources
- First paper doesn't differentiate between content and ad
- First paper considers the flat pricing model while the second paper considers per unit data charges
- Second paper allows CPs to sponsor different users differently
- The first paper considers effect of sponsorship on ISPs as well, whereas the second paper only discusses impact on users and CPs

Unified View

- One of the major conclusions of both the papers is that sponsored data may enlarge the revenue distribution between different CPs.
- First paper lays more emphasis on QoS and shows that if the ISPs capacity is sufficient, they have no incentive to enlarge the traffic cap.
- Sponsorship can reverse some of our intuition on how user demand changes with price sensitivity and the amount of ads shown by CPs

Thank You!