# Sponsored Data Plan: A Two-Class Service Model in Wireless Data Networks

# Outline

- Introduction
- Model
- Content Providers' Decisions
- ISP's Strategy

# Introduction

# Introduction

- Wireless network data plan with cap
- ISP
- Content Providers (CPs)
- Users
- Sponsored data plan

# Model

# Market with Three Parties

- A set of CPs: N
- Sponsoring CPs: S
- Ordinary CPs: O

- M users

- ISP

# User Valuation

- User's per unit traffic valuation from CP i: $g_i()$
- Total valuation with $x_i$ traffic: $\int_0^{x_i} g_i(s)ds$
- QoS index: $q_i = b_i/\hat{b}_i$
- QoS satisfaction function: $h_i(\cdot) : [0,1] \rightarrow [0,1]$

$$\int_0^{x_i} g_i(s)h_i(q_i)ds$$

# User Utility

- Per unit traffic valuation threshold: $t_i$
- $t_i$ decides traffic usage threshold: $\theta_i$
- User's utility: $\psi_i(x_i) = \int_0^{x_i} [g_i(s)h_i(q_i) - t_i]\, ds$

- Users' utility (surplus) from all CPs:

$$\psi(\mathbf{x}) = \sum_{i \in \mathcal{N}} \int_0^{x_i} [g_i(s)h_i(q_i) - t_i]\, ds$$

# User Utility Maximizing Problem

- Given QoS index vector $\mathbf{q} = (q_1, \cdots, q_N)$
- Maximizing user's utility:

$$\max_{\mathbf{x}} \qquad \psi(\mathbf{x}) = \sum_{i \in \mathcal{N}} \int_0^{x_i} \left[ g_i(s) h_i(q_i) - t_i \right] ds,$$

$$\text{s.t.} \qquad \sum_{i \in \mathcal{O}} x_i \le C, \; 0 \le x_i \le \theta_i.$$

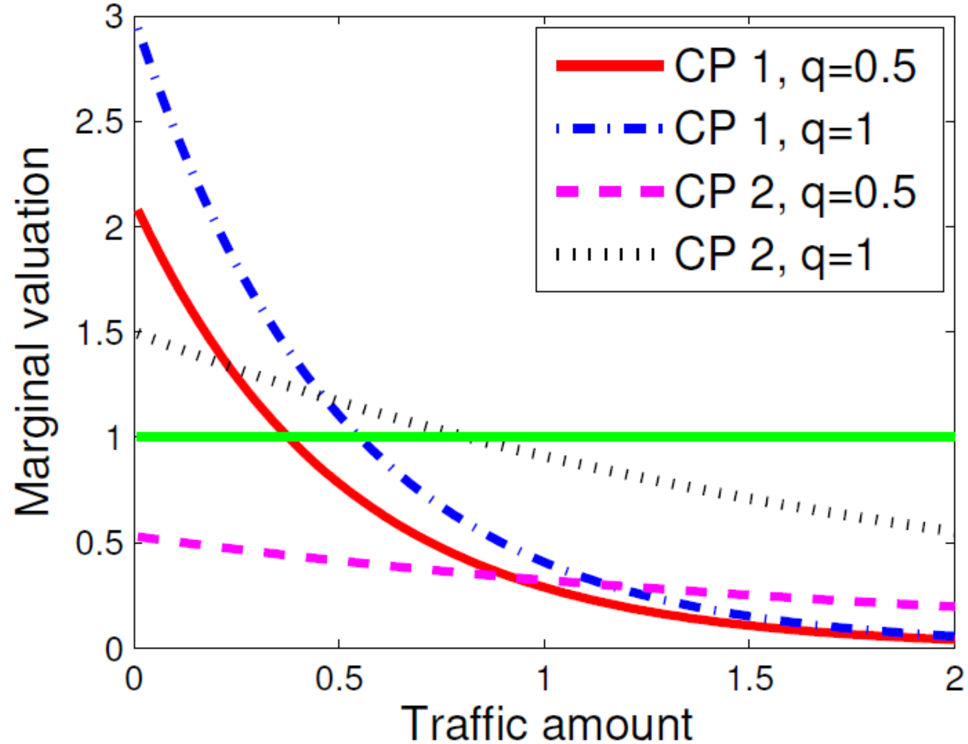
# User Utility Maximizing Problem

LEMMA 1. *A user's optimal data consumption of the content provided by CP $i$, denoted as $x_i$, is:*

$$x_i = \begin{cases} \max\left\{0, g_i^{-1}\left(\frac{t_i+\nu}{h_i(q_i)}\right)\right\} & i \in \mathcal{O}, \\ \theta_i & i \in \mathcal{S}, \end{cases} \tag{4}$$

# Conclusion on User's Side

- Traffic consumption in S is always the threshold θ
- CPs in O face competition



# ISP's Capacity

- Users' total traffic demand:

$$D(\mathbf{q}) = \sum_{i \in \mathcal{S}} M\theta_i(q_i) + M \min\left\{ \sum_{i \in \mathcal{O}} \theta_i(q_i), C \right\}$$

- When insufficient, ISP can decrease C, or $q_i$ (use proportional share mechanism)
- Equilibrium QoS index
- C increases, equilibrium QoS decreases

# CPs' Utility

- Per unit revenue of CP i: $v_i$
- Per unit cost: $c_i$
- Per unit sponsor fee: $p$
- CP's utility:

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

# ISP’s Utility

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

# Two-stage Stackelberg Game

- Players: The ISP and the set of CPs
- Step 1: ISP decides p and C
- Step 2: Each CP decides join O or S

- Backward induction: solve step 2 (subgame), and then find ISP's optimal strategy

# CPs’ Decisions

# CPs’ Decisions

- This paper derives the condition for the existence of the equilibrium.
- When there exists equilibrium…
- When there does not exist…
  - Heuristic strategy for CPs?
  - Mixed Nash equilibrium?

# Characteristics of the Outcome

- Theorem 4: When ISP’s capacity increases: QoS increases, competition reduces, benefit all CPs.

- Theorem 5: CPs with higher unit revenue or sensitive to QoS, have incentive to join sponsored plan.

# ISP’s Strategy

# ISP's Strategy

- ISP has little incentive to increase C.
- Lower C drives CPs to sponsoring.
- Then ISP charges higher sponsoring price p.

- ISP has strong incentive to enlarge capacity until QoS=1.

# Thank You!