To Peer or Not to Peer

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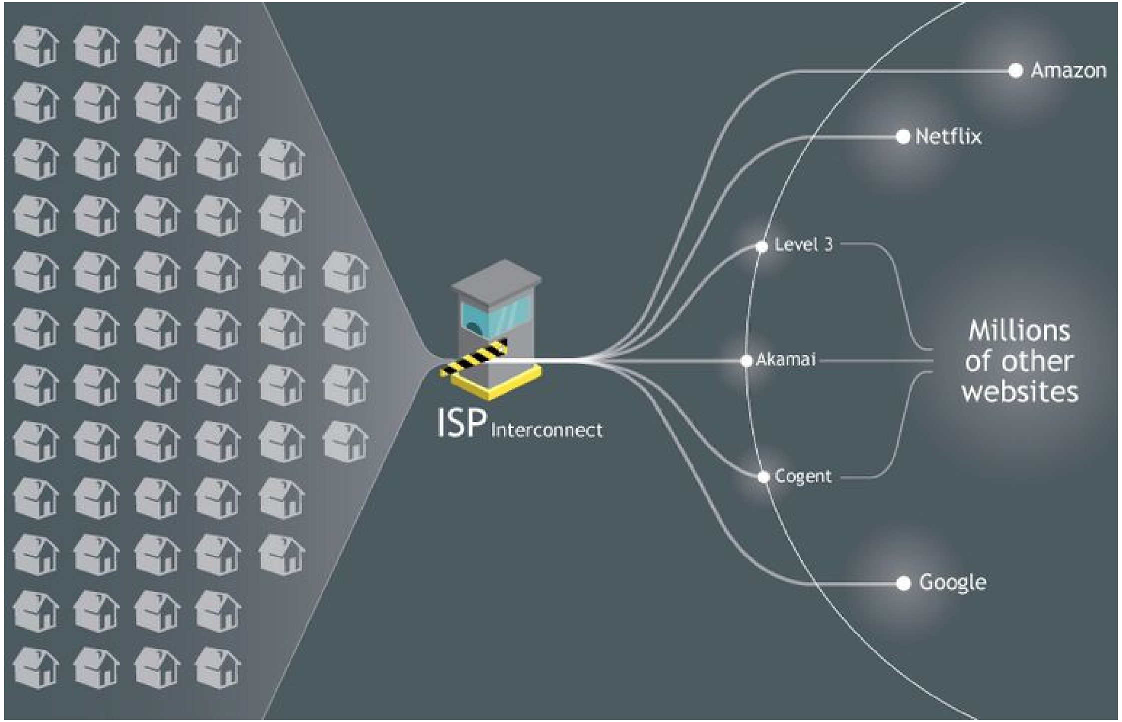
Network Preliminaries

- Customers
- Content Providers (CP)
- Internet Service Providers (ISP)
  - Transit ISP
  - Access ISP



Src: Internet Tolls And The Case For Strong Net Neutrality

What is peering

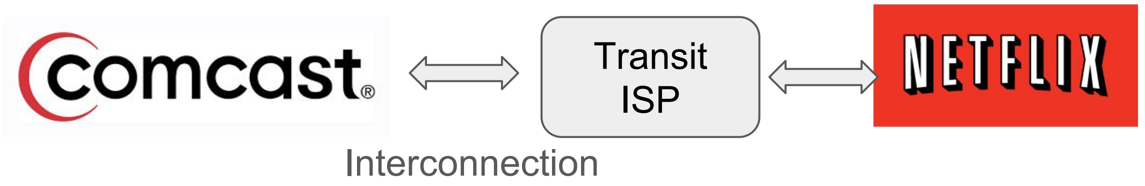
- Evolution of internet

- Traditional unpaid peering (settlement-free peering)
  Justifiable due to ‘traffic symmetry’

- Asymmetric traffic in CSP and ISP cases

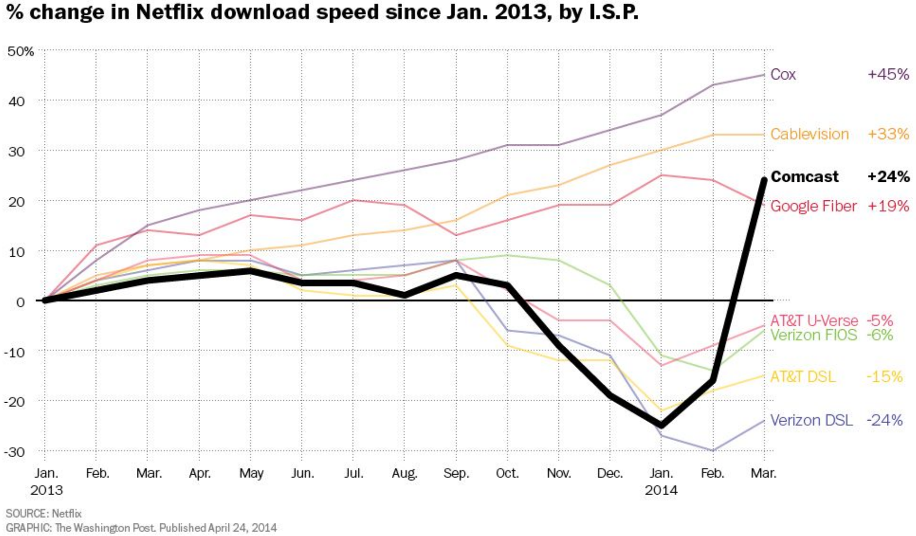
- Paid peering
  - Improved QoE
  - Fast lanes

Paid peering tussles



- Netflix Comcast deal
    - Comcast refused to increase capacity of transit ISP unless Netflix pays for it

- Beginning of Paid peering era
    - who benefits the most from the premium peering?
    - who can monetize better the superior traffic delivery quality?



Nash Bargaining Based Model

Model: Overview

- Suffices to establish a small set of agreements for premium peering directly between leading A-ISPs and CSPs

- Two types of exchanges involved :
    - Extra Infrastructure cost required for paid peering
    - New profits due to extra QoE
        - Increasing engagement time of existing customers
        - Positive incoming churn of new customers taken from competitors (both earn)

- Increased engagement time can typically be monetized only by CSPs since A-ISPs offer flat contracts

Model: Practical Takeaways

- CSPs have more ways to monetize improved QoE : pay for premium peering

- Total surplus is obtained by solving a Nash bargaining problem
  - It has to be translated into per bit prices for premium peering

- Factors affecting directionality of payments and Volume:
  - Large ISPs receive payments from CSPs, while smaller offer it for free/pay
  - Customer Loyalty - “Lock-in”
  - Uniqueness of a service by CSP

Model: Practical Takeaways

- First movers have the advantage

- Payment is not always from CSP to A-ISP for peering:
  - Smaller A-ISP has much more to gain from a premium peering relationship with an important CSP

- Balancing will require per service peering
  - Video v/s Search

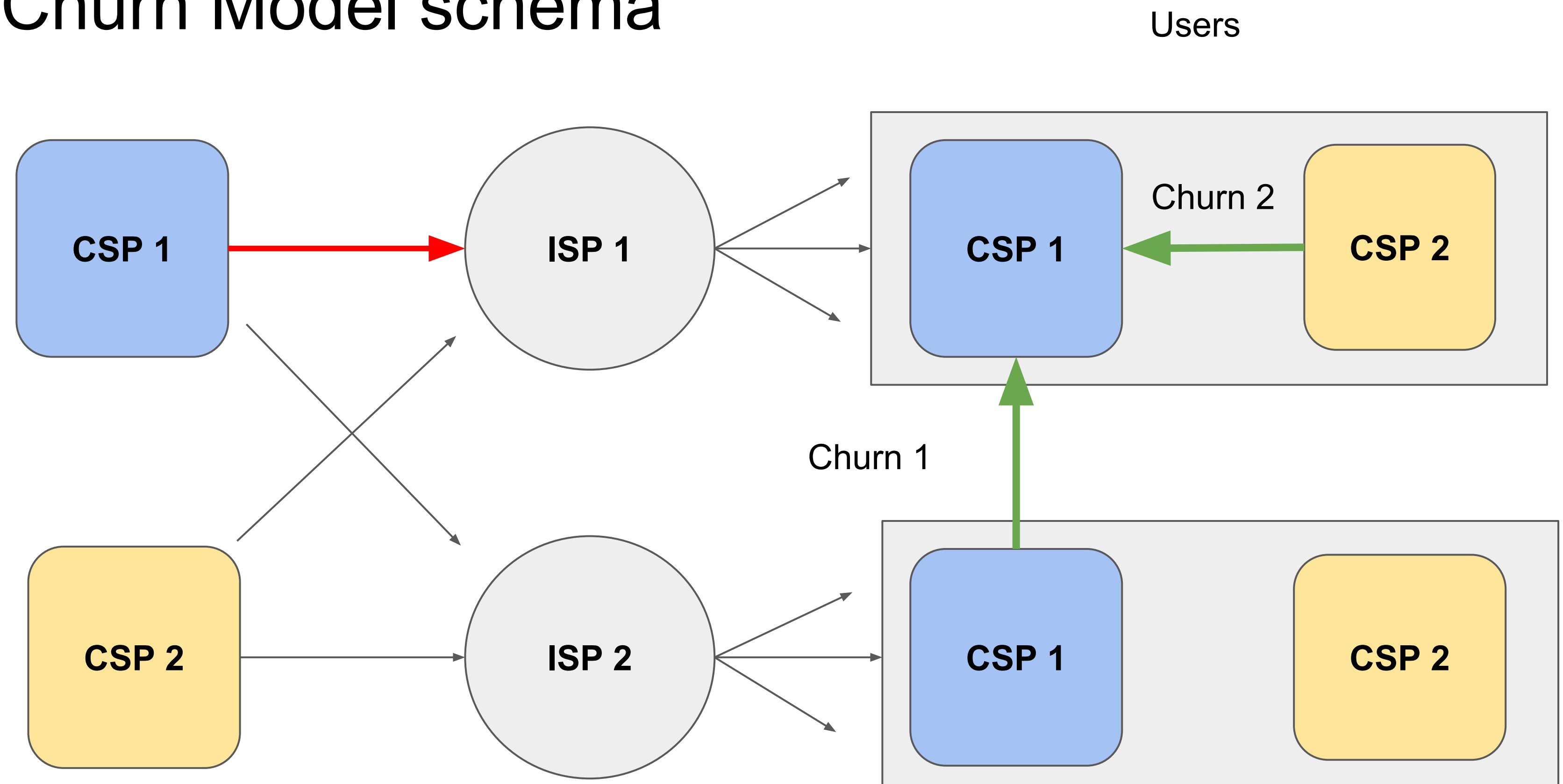
Churn Model

- Customer type

$$User\ type := (i, (s, T))$$
$$i \in ISP$$
$$T = (T_1, T_2 .. T_K)\ where\ T_k = CSP\ of\ service\ k$$
$$s \in \{1, 2, .. K\}\ where\ s\ is\ most\ valuable\ service$$

- Two phase model
  - Phase 1: Switch ISP:
    Preferred service being offered by the same CSP at premium quality at a new A-ISP
  - Phase 2: Switch CSP
    Preferred service available at higher quality at current ISP by another CSP

Churn Model schema



Probabilistic Churn Model

Phase 1: Churn across ISPs

$$\gamma = (1 - \beta(i))h(s)$$

γ = Probability of transition

$\beta(i)$ = loyalty to ISP i

$h(s)$ = Probability to switch if service s is offered at better quality

Phase 2: Churn across CSPs

$$\gamma = (1 - \theta(T_s))g(s)$$

γ = Probability of transition

$\theta(T_s)$ = stickiness to CSP T_s

$g(s)$ = Probability to switch CSP if service s is offered at better quality

Profit Modelling (before peering)

CSP revenue

- Total subscription revenue
- Advertisement revenue
  (Engagement time) X (click rate) X (profit per click)

CSP cost

- Payment for transit
  (Traffic volume) X (unit price for transit service)

ISP revenue

- Flat rate pricing
  (# customers) X (revenue per customer)

ISP cost

- Payment for transit
  (Traffic volume) X (unit price for transit service)

Profit Modelling (after Peering)

- No transit cost, but will have to pay peering cost

- Parameter changes in CSP
  - Enhanced quality of service affect subscription fees, engagement time, click rate and revenue per click.
  - Enhance quality also increases traffic load

- Parameter changes in ISP
  - Enhanced quality of service affects revenue per customer
  - Driving force for churn of customers

Nash Bargaining Solution

Fair sharing of total excess profit : $U = \hat{V}_i - V_i + \hat{V}_x - V_x$

Nash bargaining problem

$$\max_{z_i + z_x = U} (z_i - V_i)(z_x - V_x)$$

z_i, z_x = new fair profits for ISP, CSP

V_i, V_x = old profits for ISP, CSP

$\hat{V}_i, \hat{V}_x$ = new actual profits for ISP, CSP

Nash bargaining solution

Payment from CSP to ISP $(w_x) = \hat{V}_x - z_x$

$$w_x = \frac{1}{2}\left[(\hat{V}_x - V_x) - (\hat{V}_i - V_i)\right]$$

Parameterization of Model : Classifying assumptions

- **Service Parameters**
  - **Probability of A-ISP Churn:** Linear Increase : Search< Video< OSN< Gaming
  - **Probability of CSP Churn:** Linear but reverse order
  - **Postpeering traffic Rates:** For video: quality increased,resulting in larger traffic

- **A-ISPs**
  - **A-ISP Stickiness:** Assumed identical, though with a different size customer base
  - Major Contributor to A-ISP profits is OSN Services

Parameterization of Model : Classifying assumptions

- **CSPs:** Ad-powered CSPs and Subscription-based CSPs
  - **CSP Stickiness:** assumed identical for all CSPs
  - **Postpeering advertising rates:** assumed to remain same with increased quality

- **General**
  - **Market Conditions:** Initially assume no peering agreements and both A-ISPs and CSPs face same transit cost

Stackelberg Game Theoretic Model

Overview

- Single ISP transacts with multiple CPs
- Analysis using Stackelberg leader-follower game
  ISP: leader CSP: follower
- Infrastructural investments by CSPs and ISP

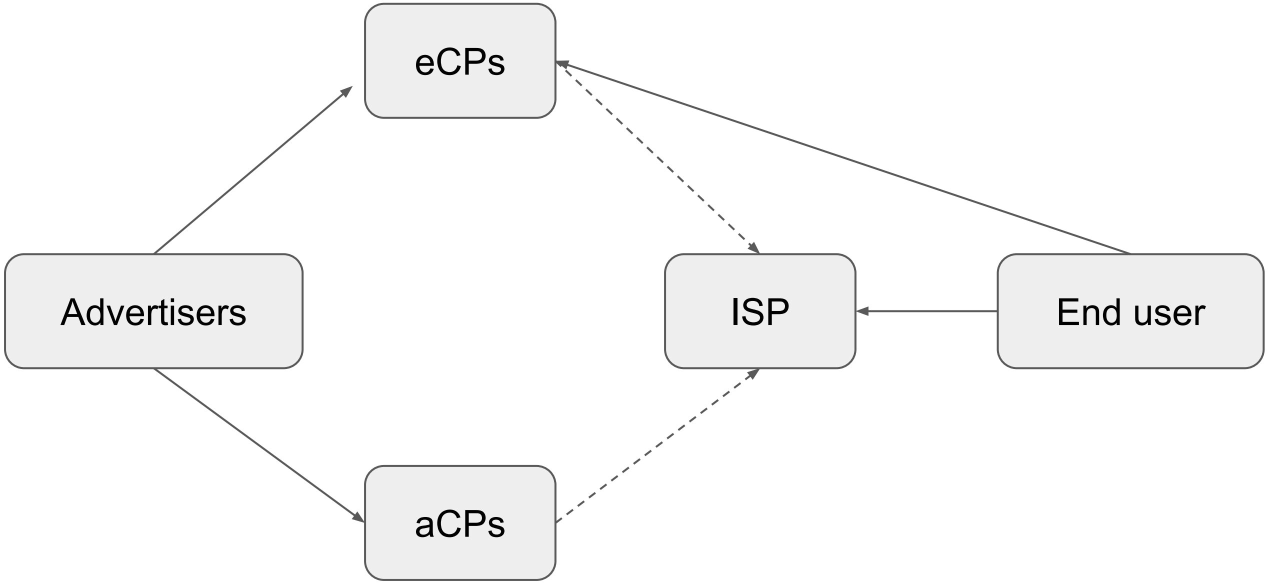
Model

- CSP
  - aCP: Advertisement powered CSPs (e.g. YouTube)
  - eCP: Subscription + ad powered CSPs (e.g. Hulu)

  No competition amongst CSPs
  No CSP churning (each CSP has its own customer base)

- ISP
  - Usage based pricing

Money flow



Main Research Questions

- Which parameters are crucial to determine optimal peering prices?
- How is the volume per transaction influencing the paid peering charges?
- What is the impact of paid peering on the profits of the CPs of different types?

Parameters (a lot :P)

- Cobb-Douglas demand function

$$D_a = d_a c_a^u t^w e^{-sb_a/\theta}$$

$$D_e = d_e c_e^u t^w e^{-sb_e/\theta} e^{-p/\theta_e}$$

- Profits

$$\pi_{isp} = n_e \rho_e (s + q_e) + n_a \rho_a (s + q_a) - kt.$$

$$\pi_a = \rho_a (\gamma_a / b_a - q_a) - z c_a$$

$$\pi_e = \rho_e (\gamma_e / b_e + p / b_e - q_e) - z c_e$$

Stackelberg Game

- Leader Step
  - ISP chooses peering charges (for aCP and eCP) and infrastructural investment by anticipating decisions of CSPs in follower step

- Follower Step
  - eCP chooses subscription charges and infrastructural investment
  - aCP chooses infrastructural investment

Major Results

- Optimal subscription charge by eCP
  - End-users are burdened with peering charges
  - Inelastic users can be charged more
  - Price p is chosen so that the net profit per transaction of the eCP is always θe

$$p = \theta_e + q_e b_e - \gamma_e$$

- Optimal peering charges
  - In the case of an aCP, for small value of u, the ISP acts as a monopolist and takes away all the profits from the aCP.
  - For small values of u the ISP and the eCP obtain similar profit per transaction, equal to θe

$$q_a = \frac{\gamma_a(1-u) - b_a s u}{b_a}$$

$$q_e = \frac{\theta_e(1-u) - b_e s}{b_e}$$

Major Results

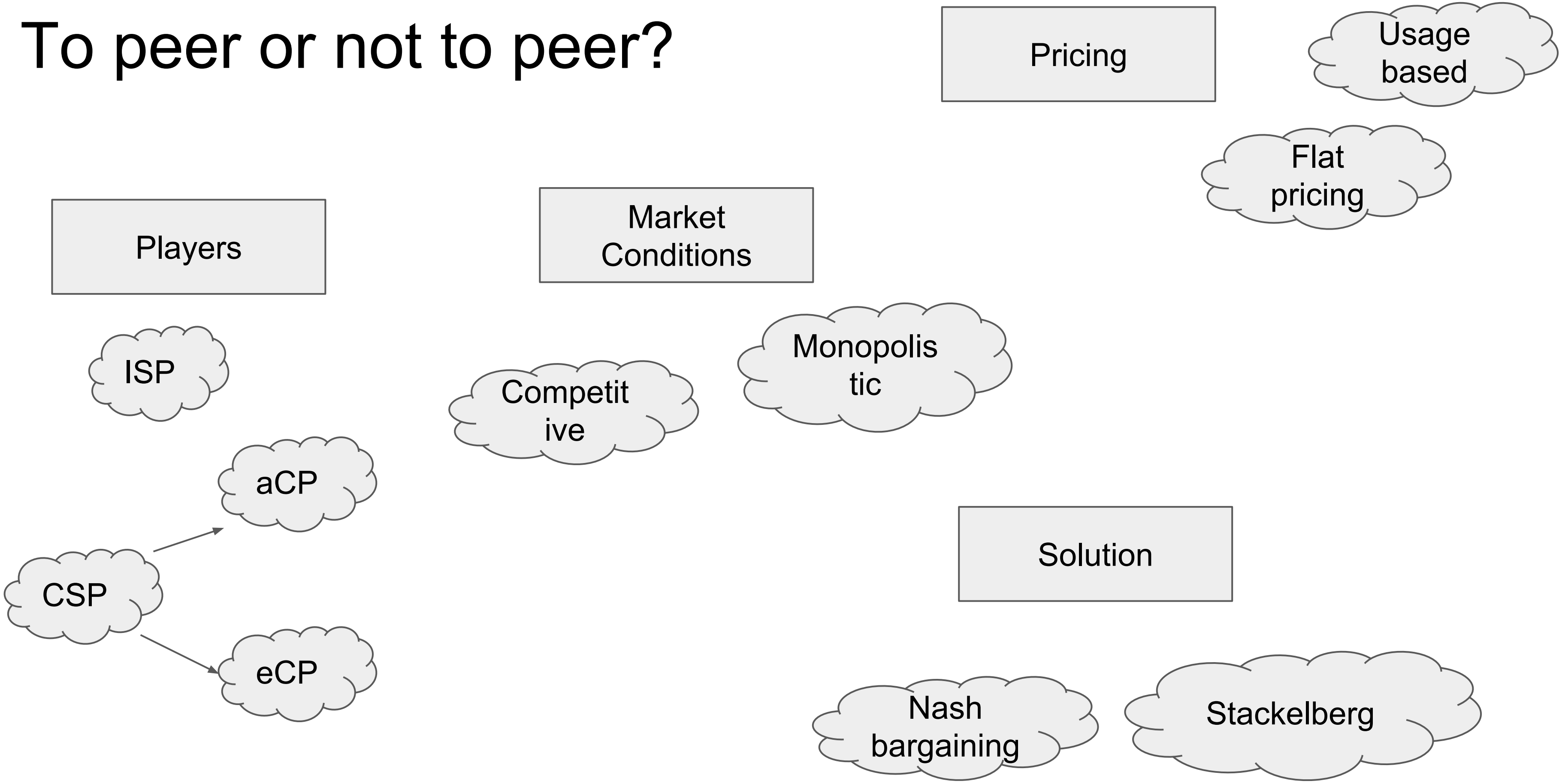
- Unit payments for heavy traffic applications are lower
  - High b_a, b_e imply small (possibly negative) q_a, q_e
  - Incentive of the ISP to offer quantity discounts to volume-intensive CPs for delivering their content over the fast-lane
- Exact number of eCPs and aCPs in choosing the optimal payments
  - Negotiations can be made on bilateral basis (without considering other market players)

Discussion

Discussion

- What if eCPs are price takers?
- Each CP has own customer base. No churn modelling
- Net neutral?

To peer or not to peer?



Thank You