Peering amongst Internet Service Providers

EE758 Internet Economics Project

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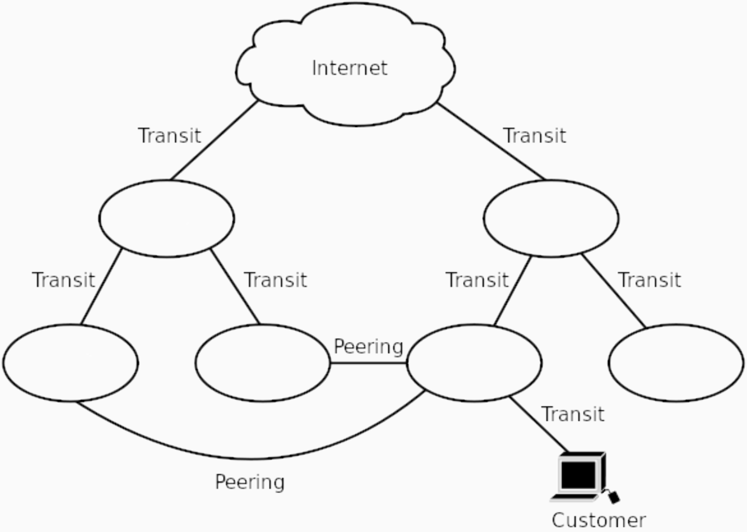
Peering fundamentals



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- Transit relationships usually exist between a smaller and a larger network, where the larger network carries the smaller network’s data for a fee.
- Peering relationships usually exist between large networks of similar size as both networks can benefit equally from the agreement.

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- Their only concern is to connect with other Tier 1 (and some Tier 2) networks. These make up the core of the Internet.
- At the very bottom of the hierarchy, you have Tier 3 networks. These networks purchase access to Tier 1 and Tier 2 networks so that they can then provide Internet access to home users

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- Hot-potato routing is the practice of passing traffic off to another autonomous system as quickly as possible, thus using their network for wide-area transit.
- Cold-potato routing is the opposite, where the originating autonomous system holds onto the packet until it is as near to the destination as possible.

Internet Interconnection and the Off-Net pricing principle [Laffont et al., 2001]

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- They contrast the Internet peering problem with that of telephone interconnection
- They focus on finding the price that competitive ISPs would charge their customers in the presence of a access charge based peering arrangement

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- Consumers majorly only download data while websites mostly send out data.
- In the simple benchmark described in the short paper assigned to us they also assume that there is no money transfer directly between consumers, websites using micro-payments tied to the data.

The Simple benchmark

Two perfectly substitutable ISPs (backbones) compete in a Bertrand game like setting for end users.

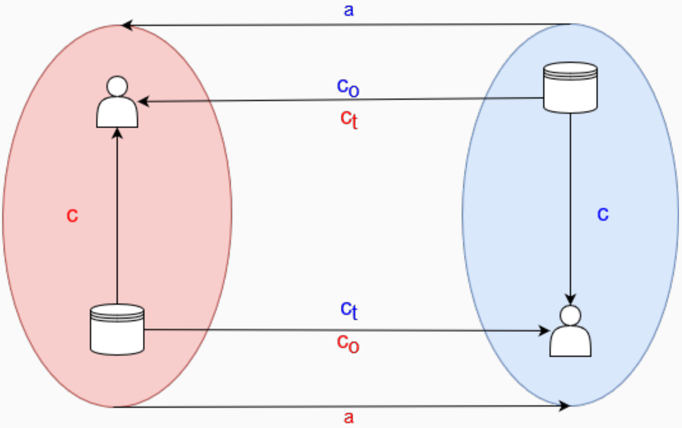

Figure 2: Costing (c, c_o, c_t) and charge (a) transfer model. Note that $c = c_o + c_t$

Equilbrium Pricing

Theorem

In competitive equilibrium, the backbones price traffic at the off-net cost. That is, they set per unit charges p to the consumers and $\overline{p}$ to the web sites as if their connections were entirely off-net

i.e $p = (c_t - a)$, $\overline{p} = (c_o + a)$

Suppose that the two networks have market share α_1 and α_2 of the consumer segment. The intuition behind the proof can be understood by the following analysis.

Equilbrium Pricing

Traffic Stealing

Suppose that network i attracts web site from its rival. The net cost incurred is $\alpha_i[c - (c_t - a)] + \alpha_j[(c_o + a) - 0] = (c_o + a)$

Traffic Creation

The net cost incurred by network i for a new web site's traffic is $\alpha_i[(c\_p_i) - 0] + \alpha_j[(c_o + a) - 0]$ where p_i is the price charged to consumers. At equilibrium $p_i = (c_t - a)$ and we again get the off-net cost to be $(c_o + a)$

Similarly, the net cost of stealing a consumer from the rival network, as well as the net cost of new consumer traffic when web sites are charged their off-net cost $(c_o + a)$, are both equal to $(c_t - a)$. Hence by the principle of marginal costing this is the equilibrium.

Comparison to telephone interconnection

The key difference is a missing price: receivers do not pay i.e $p = 0$. The perceived marginal price of outgoing traffic in [Laffont et al., 1998] is $c + \alpha_j(a - c_t)$. Comparing to the above case the price of sending traffic is clearly higher. Hence the missing payment causes the costs to be reallocated.

Extension

The authors extend the above preliminary result in the following directions in their long paper.

- Robustness of the off-net-cost pricing principle : it extends to an arbitrary number of backbones, mixed traffic patterns, variable demands, multiple classes of traffic (QOS), customer cost heterogeneity, network-based price discrimination, and backbone differentiation.

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- Robustness of the off-net-cost pricing principle : it extends to an arbitrary number of backbones, mixed traffic patterns, variable demands, multiple classes of traffic (QOS), customer cost heterogeneity, network-based price discrimination, and backbone differentiation.
- Policy Analysis : They look at socially optimal access charges. Interestingly, optimal "Ramsey" access charges are driven by two forces: elasticities of users to access charges and externalities caused by "marquee websites".

Paid Peering among Internet Service Providers [Shrimali and Kumar, 2006]

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- It is shown that ISP with lower marginal cost acts as a monopolist, and the other provider strategically routes traffic, splitting between hot potato and cold potato routing.
- Though this outcome is inefficient as compared to socially optimal solution, both the ISPs are strictly better off when compared to not peering.
- Under certain conditions, it can be shown that the monopolist has an incentive to upgrade the capacity of its links

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- The cost to send traffic across the peering links is zero
- The internal link costs depend only on the total flows on these links.
- The ISPs are individually rational. This means that the ISPs would participate in trade, i.e., accept proposed pricing schemes and choose flow splits, only if they benefit from the trade

The Model

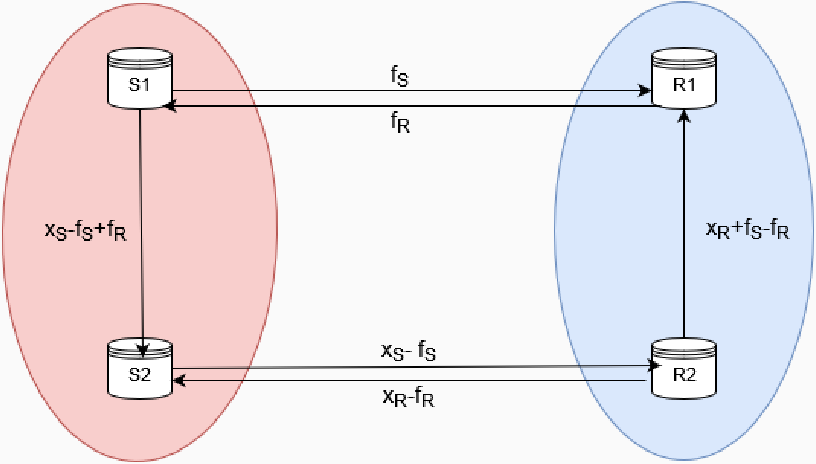

Figure 3: The peering model

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The Social Problem

The social planner is faced with the following problem

$$\min_{0 \leq f_s \leq x_s, 0 \leq f_s \leq x_s} J_{total}(f_s, f_r) = J_s(f_s, f_r) + J_r(f_s, f_r)$$

Noting that this only depends on the difference $f_d = f_s - f_r$ we can rewrite it as a problem of one variable.

$$\min_{-x_r \leq f_d \leq x_s} J_{total}(f_d) = C_s(x_s - f_d) + C_r(x_r + f_d)$$

Proposition 1

The social planners problem has a unique solution f_d^{soc}, where $0 \leq f_d^{soc} \leq x_s$

Monopolistic Behavior

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- We analyze all the above equation with $f_R = 0$ which allows R to act as Monopolist
- We obtain two differential expression on solving the problem with the above constraint
- The final results being p_R^m and f_S^m

The full Nash Game

Theorem 1

In the full Nash Game defined earlier $f_R = 0$ in any subgame-perfect equilibrium

Theorem 2

In the Nash game, a subgame-perfect equilibria satisfying the following equations exists

$$p_R = -\frac{\partial \tilde{J}_S}{\partial f_S}(f_S^m, 0)$$

$$f_R = 0$$

$$p_S > -\frac{\partial \tilde{J}_S}{\partial f_S}(f_S^m, 0)$$

$$f_S = f_S^m$$

The full Nash Game

Theorem 3

Under linear pricing, the monopoly outcome is inefficient. In addition, both ISPs are strictly better off due to peering. That is

$$J_S^{peering} < J_S^{no_peering}$$

$$J_R^{peering} < J_R^{no_peering}$$

Monopolist is identified as the player with lower marginal cost after solving the equation of the Nash Game

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- The monopolist has an incentive to upgrade its capacity if and only if

$$\frac{\partial \tilde{J_R^m}}{\partial \theta_R^D} + f_S^m \frac{\partial^2 \tilde{J_S^m}}{\partial \theta_R^D \partial f_S^m} \leq 0$$

  In addition, if

$$\frac{\partial^2 \tilde{J_R^m}}{\partial \theta_R^D \partial f_S^m} \leq 0 and \frac{\partial^2 \tilde{J_R^m}}{\partial \theta_R^D \partial f_S^m} \leq 0$$

  then the monopolist has more of an incentive to upgrade capacity when peering as compared to not peering, i.e.,

$$\frac{\partial \tilde{J_R^{peering}}}{\partial \theta_R^D} \leq \frac{\partial \tilde{J_R^{no-peering}}}{\partial \theta_R^D}$$

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- [Shrimali and Kumar, 2006] show that given the cost functions how would individually rational ISPs charge each other and subsequently route their traffic.
- These two approaches can be naturally integrated, the p_r, p_s, f_s, f_r values obtained by [Shrimali and Kumar, 2006] can be used to compute the average access charge that the ISPs would charge each other. And subsequently the price to the customers can be decided using the off-net principle.

Questions?

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