A simple two-sided market model with side-payments and ISP service classes

George Kesidis
CS&E and EE Depts, The Pennsylvania State University, University Park, PA, 16802
kesidis@gmail.com

***Abstract*—We consider a simple two-sided market model of an Internet Service (access) Provider (ISP) and Content Provider (CP, over commodity Internet access) on a platform of user-demand. Though the model does not consider provider competition and resource congestion, it does consider advertising revenue, multiple ISP service classes, separate price sensitives for each provider type, and side-payments from CP to ISP [16]. We argue that side-payments are effectively in play even under network-neutrality regulations owing to considerations in Service-Level Agreements (SLAs) of asymmetries in traffic aggregates at boundaries (NNIs) between eyeball ISPs and transit ISPs, the latter serving the CPs remote to the eyeball ISPs. Finally, we consider a game between content providers based on "managed" and commodity-Internet-access services.**

I. INTRODUCTION

Network neutrality continues to be debated as its core economic issues as described in, *e.g.*, [2], [15], [5], have not been resolved. The debate concerns all participants in the enormous and growing Internet economy: Internet service (access) providers (ISPs), content providers (CPs, more generally providers of application services), end-users/consumers, and government regulators.

Initially, the network neutrality debate concerned unilateral actions by ISPs to limit certain applications, particularly peer-to-peer file sharing, congesting access networks, particularly CMTS. It since transformed into guidelines, *e.g.*, preventing ISPs from unilateral discrimination of services (packet flows) based on application type. Service differentiation is, however, permitted at the behest of the end-user. This service differentiation could take the form of increased bandwidth to, *e.g.*, accommodate high-definition video streams (naturally at an additional cost to the end-users for such premium service).

The debate over sharing of the advertising revenues[1] of a CP have also been cast in a network neutrality context. Some ISPs have apparently argued that users do not explicitly request advertising and thus some CPs are transmitting (and profiting from) unauthorized content over the ISP's infrastructure, even going so far to prune advertising from delivered content [7]. Naturally, CPs claim that users implicitly approve of advertising associated with free (to the user) services such as web search and email, and access to content such as video and news. Complicating the role of eyeball ISPs[2] [9] with respect to content is the fact that many are themselves also content providers (over "managed services" they provide to their end-users), and thus in competition with some CPs that they enable over their commodity Internet service[3]. In the following, we assume that CPs may have subscription revenue [12] directly from end-users (*cf.*, π_{CP}) and per-user advertising revenue (*cf.*, a).

Network neutrality regulations also prevent ISPs from demanding side payments from content providers for access to the ISP's end-users/subscribers. With regard to the latter, neutrality rules do not preclude asymmetric Service-Level Agreements (SLAs) at network-to-network interfaces (NNIs, or peering points) that are (neutrally) based on traffic *aggregates*. In this way, an eyeball ISP can effectively demand additional payment from the transit ISP of a large (*e.g.*, video) content provider. The transit ISP will naturally pass on these costs to the CP or be squeezed out of business forcing the CP to directly engage with the ISP - either way, a side-payment from the CP to the eyeball ISP effectively ensues. In the following, we assume an "effective" side payment per-user from ISP to CP (*cf.*, σ).

Since the onset of the neutrality debate, researchers have studied parsimonious models of the Internet marketplace to gain insight into the economic forces in play, *e.g.*, [12]. Performance is often assessed based on the Bertrand-Nash equilibria of noncooperative, decentralized games, and in terms of dynamical convergence to these equilibria, often considering limited resources (particularly bandwidth) as in classical Cournot games. For example, games involving end-users and content providers on an ISP platform were studied in [6], [11]. Shapley values, indicating fair division of revenue with a coalition (or cooperative game), are used to argue for side-payments between ISPs and CPs in [9], [10].

In this paper, we consider a noncooperative game between a single (or cooperating collective) CP and a single eyeball ISP on a platform of end-users served by both, *i.e.*, a two-sided market. We neither consider inter-provider competition herein nor the effects of limited resources causing congestion, *e.g.*, [14], [8], [4]. We assume that end-users can choose between a best-effort and premium service, the latter, *e.g.*, in-

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[1]Note that in broadcast television, (far less targeted) advertising is shared by the parties in play (including embedded advertising in content and commercials mounted by the national broadcaster or local affiliate stations). This is not to say that things are always rosy among content providers, broadcasters and cable operators, *e.g.*, [13].

[2]Here, ISPs that service end-users.

[3]Somewhat conversely, in the context of the Digital Millennium Copyright Act (DMCA) and associated debate over illegal file-sharing (again, the traffic volume of which was a trigger for the network neutrality debate), some have argued to hold ISPs accountable for associated loss of revenue to holders of copyrighted content.

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volving increased bandwidth allocation to accommodate high-definition video content.

This note is organized as follows. In Section II, we consider a two-sided model with eyeball ISP and separate-party CP, the latter using the ISP's commodity-Internet service to access the eyeball ISP's subscribers/end-users. A regulated [1] side payment is assumed from CP to ISP. In Section III, we consider a simple game between competing content providers: the aforementioned and a "managed" services provider affiliated with the ISP. Finally, the paper concludes with a summary in Section IV.

II. ISP and separate-party CP illustrative example

Consider a single eyeball ISP and a single CP operating on a fixed platform of end-users. For a given set of prices, the end-users can be identified as belonging to one of two types: those who and willing to pay for premium service (subscript H) and those who are not (subscript L). The service may be "premium" in terms of bandwidth, reliability, priority, *etc.*,

Let N be the number of end-users based on a base ISP subscription-price $\pi_{\mathsf{L}} > 0$ that is fixed. For each of its premium subscribers, the ISP charges

$$\pi_{\mathsf{H}} \quad \geq \quad \pi_{\mathsf{L}}.$$

The CP charges $\pi_{\mathsf{CP}} \geq 0$ for each end-user[4]. Let $a \geq 0$ be the mean advertising revenue per end-user to the CP, treated here as an exogenous parameter. Let $\sigma \geq 0$ the side-payment per end-user from the CP to the ISP, which we also assume is (regulated) fixed [1], [3].

The number of non-premium subscribers is

$$n_{\mathsf{L}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) \quad \leq \quad N,$$

where n_{L} is nondecreasing in π_{H} and n_{L} is nonincreasing in π_{CP}, so that

$$n_{\mathsf{L}}(\infty, 0) \quad = \quad N.$$

So, if π_{CP} is sufficiently high, some end-users ($N - n_{\mathsf{L}}(\infty, \pi_{\mathsf{CP}})$) will simply opt out of the whole single-ISP/single-CP system (even in the nonpremium category L). The number of premium subscribers is

$$n_{\mathsf{H}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) \quad = \quad n_{\mathsf{L}}(\infty, \pi_{\mathsf{CP}}) - n_{\mathsf{L}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}).$$

The ISP and CP utilities are, respectively,

$$\begin{aligned} U_{\mathsf{ISP}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) &= (\pi_{\mathsf{L}} + \sigma) n_{\mathsf{L}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) + (\pi_{\mathsf{H}} + \sigma) n_{\mathsf{H}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) \\ &= (\pi_{\mathsf{H}} + \sigma) n_{\mathsf{L}}(\infty, \pi_{\mathsf{CP}}) - (\pi_{\mathsf{H}} - \pi_{\mathsf{L}}) n_{\mathsf{L}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) \\ U_{\mathsf{CP}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) &= (\pi_{\mathsf{CP}} + a - \sigma)(n_{\mathsf{L}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) + n_{\mathsf{H}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}})) \\ &= (\pi_{\mathsf{CP}} + a - \sigma) n_{\mathsf{L}}(\infty, \pi_{\mathsf{CP}}) \end{aligned}$$

Clearly, the ISP controls π_{H} ($\geq \pi_{\mathsf{L}}$) and the CP controls π_{CP}.

For a simple specific example, we can take

$$n_{\mathsf{L}}(\pi_{\mathsf{H}}, \pi_{\mathsf{CP}}) \quad = \quad N \exp(-\gamma_{\mathsf{C}} \pi_{\mathsf{CP}}) \tanh(\gamma_{\mathsf{H}}(\pi_{\mathsf{H}} - \pi_{\mathsf{L}})),$$

for parameters $\gamma_{\mathsf{H}}, \gamma_{\mathsf{C}} > 0$ depending on demand sensitivities to price [11].

[4]A simple extension involves two-tier pricing by the CP as well.

One can show directly by differentiation that U_{CP} is unimodal. So, the Nash equilibrium of this two-player (ISP and CP) game, is

$$\begin{aligned} \pi^*_{\mathsf{CP}} &= \arg\max_{\pi_{\mathsf{CP}}} U_{\mathsf{CP}}(\pi_{\mathsf{CP}}) \;=\; (\gamma_{\mathsf{C}}^{-1} - a + \sigma)^+ \qquad (1) \\ \pi^*_{\mathsf{H}} &= \arg\max_{\pi_{\mathsf{H}}:\pi_{\mathsf{H}} \geq \pi_{\mathsf{L}}} U_{\mathsf{ISP}}(\pi_{\mathsf{H}}, \pi^*_{\mathsf{CP}}) \;\approx\; 0.65\gamma_{\mathsf{H}}^{-1} + \pi_{\mathsf{L}} \end{aligned}$$

where $x^+ := \max\{x, 0\}$. Regarding the factor 0.65 of in π^*_{H}: the unique positive root of $f(x) := 1 - \tanh(x) - x(1 - \tanh^2(x))$ (depicted in Figure 1) is $x^* \approx 0.65$, where $f(x)$ is positively proportional to $\partial U_{\mathsf{ISP}}(\pi_{\mathsf{H}}, \pi^*_{\mathsf{CP}})/\partial \pi_{\mathsf{H}}$ when $x = \gamma_{\mathsf{H}}(\pi_{\mathsf{H}} - \pi_{\mathsf{L}})$. Thus, $U_{\mathsf{ISP}}(\cdot, \pi^*_{\mathsf{CP}})$ is also unimodal.

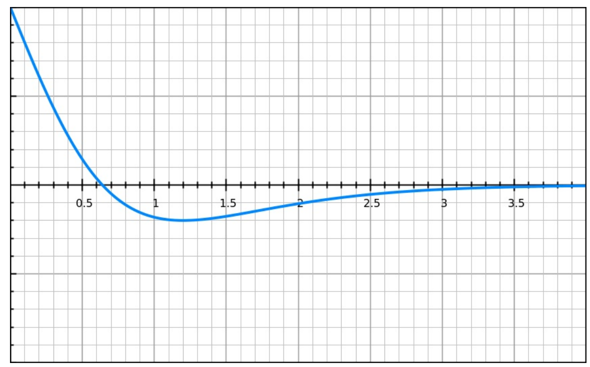

Fig. 1. $f(x) := 1 - \tanh(x) - x(1 - \tanh^2(x))$ from graphsketch.com

So, the above Nash equilibrium is unique. Note that $\pi^*_{\mathsf{CP}} > 0$ when

$$\gamma_{\mathsf{C}}^{-1} - a + \sigma \quad > \quad 0, \qquad (2)$$

and if so the Nash equilibrium utilities are

$$\begin{aligned} U_{\mathsf{CP}}(\pi^*_{\mathsf{H}}, \pi^*_{\mathsf{CP}}) &= N\gamma_{\mathsf{C}}^{-1} \exp(-1 + \gamma_{\mathsf{C}}(a - \sigma)) \;=:\; U^*_{\mathsf{CP}} \\ U_{\mathsf{ISP}}(\pi^*_{\mathsf{H}}, \pi^*_{\mathsf{CP}}) &= (\pi_{\mathsf{L}} + \sigma + x^*\gamma_{\mathsf{H}}^{-1}(1 - \tanh(x^*)))U^*_{\mathsf{CP}} \;=:\; U^*_{\mathsf{ISP}} \end{aligned}$$

On the other hand, if (2) does not hold, then $\pi^*_{\mathsf{CP}} = 0$, and

$$U^*_{\mathsf{CP}} \quad = \quad (a - \sigma)^+ n_{\mathsf{L}}(\infty, 0) \;=\; (a - \sigma)^+ N,$$

but the expression for U^*_{ISP} is unchanged.

For this simple model, we now make some direct observations of how the Nash equilibrium utilities $(U^*_{\mathsf{CP}}, U^*_{\mathsf{ISP}})$ depend on the parameters $\pi_{\mathsf{L}}, a, \sigma, \gamma_{\mathsf{C}}, \gamma_{\mathsf{H}}$.

First note that if $\pi_{\mathsf{L}}, \sigma, \gamma_{\mathsf{H}}$ are fixed, then U^*_{CP} and U^*_{ISP} are positively proportional. In particular, increasing advertising revenue a for the CP benefits *both* ISP and CP players. If (2) does not hold, say because advertising revenue is high, the CP is incented to set subscription fees to zero, *i.e.*, $\pi^*_{\mathsf{CP}} = 0$, so that the CP's only source of revenue is advertising.

Intuitively, advertising revenue is shared through the side payment, σ. Obviously, U^*_{CP} monotonically decreases with σ. However, excessive side-payments may serve to diminish U^*_{ISP} as well. This is intuitive since increased side-payments σ compels the CP to pass on costs to the end-users by increasing its subscription price π_{CP} (recall (1)), thus decreasing the number of end-users in play for both CP and ISP. The regulator's selection of the side-payment that maximizes U^*_{ISP} is easily computed as

$$\sigma^* \quad = \quad \gamma_{\mathsf{C}}^{-1} - \pi_{\mathsf{L}} - x^*\gamma_{\mathsf{H}}^{-1}(1 - \tanh(x^*)).$$

III. Content provision by managed or commodity-Internet service

Now consider two competing content providers, *e.g.*, of a video-on-demand (VoD) type of provider over "managed" services affiliated with the eyeball ISP, and the other the remote CP above providing content over commodity Internet access (which is also enabled by the eyeball ISP of course). The managed-services content provider's subscription charge is π_{M}.

The number of *active* end-users is determined by the minimum subscription charge, $\min\{\pi_{\mathsf{CP}}, \pi_{\mathsf{M}}\}$, *i.e.*, $N\exp(-\gamma_{\mathsf{C}}\min\{\pi_{\mathsf{CP}}, \pi_{\mathsf{M}}\})$. We assume that subscription costs satisfy

$$\pi_{\mathsf{M}} \quad > \quad \pi_{\mathsf{CP}},$$

so that the number of active end-users is $N\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}})$. In the following, we will also assume that the the CP's advertising revenue per end-user is sufficiently large so that

$$a - \sigma \quad > \quad \gamma_{\mathsf{C}}^{-1}, \tag{3}$$

i.e., that (2) is false. For the following game, this will again imply that that at Nash equilibrium, $0 = \pi^*_{\mathsf{CP}} < \pi^*_{\mathsf{M}}$ so that the number of active end-users is just N. We also assume that the managed-services provider has no advertising revenue (and makes no side-payments to the eyeball ISP, of course). Finally, we assume that due to loyalty or inertia (or "stickiness" collectively [3]), the content provider with the lowest subscription cost does *not* capture all of the end-users. Instead, we assume that the number of end-users subscribing to the managed-services provider is proportional to $\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{M}})$.

So, the revenues of the content providers are:

$$U_{\mathsf{M}} \;=\; \frac{\pi_{\mathsf{M}}\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{M}})}{\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}}) + \exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{M}})}\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}})N$$

$$U_{\mathsf{CP}} \;=\; \frac{(\pi_{\mathsf{CP}} - \sigma + a)\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}})}{\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}}) + \exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{M}})}\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}})N$$

For this revenue model under (3), U_{CP} is decreasing in π_{CP}. This is an immediate consequence of the fact that $\partial U_{\mathsf{CP}}/\partial\pi_{\mathsf{CP}}$ is positively proportional to

$$(1-\gamma_{\mathsf{C}}(a+\pi_{\mathsf{CP}}-\sigma))\mathrm{e}^{-\gamma_{\mathsf{C}}\pi_{\mathsf{CP}}} + (1-2\gamma_{\mathsf{C}}(a+\pi_{\mathsf{CP}}-\sigma))\mathrm{e}^{-\gamma_{\mathsf{C}}\pi_{\mathsf{M}}}$$

So, we can take $\pi^*_{\mathsf{CP}} = 0$ and

$$U_{\mathsf{M}} \;=\; \pi_{\mathsf{M}}\frac{\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{M}})}{1+\exp(-\gamma_{\mathsf{C}}\pi_{\mathsf{M}})}N.$$

The maximizing subscription price U_{M} is $\pi^*_{\mathsf{M}} = y^*/\gamma_{\mathsf{C}}$ where y^* (> 1) is the unique solution of $1 + \exp(-y) = y$. Thus, under (3) the Nash equilibrium revenues for this model are

$$U^*_{\mathsf{M}} = (y^* - 1)N/\gamma_{\mathsf{C}} \quad \text{and} \quad U^*_{\mathsf{CP}} = (a-\sigma)N/y^*.$$

So, a (regulated) side payment per end-user of

$$\sigma \;=\; a - y^*(y^*-1)/\gamma_{\mathsf{C}}$$

results in equal revenue for the content providers.

IV. Summary

We have studied a simple two-sided market model of an ISP and CP on a platform of user-demand, as we previously did in [1] for a linear demand-response in total price to the end-users. Though the initial model does not consider like-provider competition and congestion, it does consider advertising revenue, multiple ISP service classes, separate price sensitives for each provider type, and side-payments. Side-payments are effectively in play even under network-neutrality regulations owing to SLAs between eyeball ISPs and transit ISPs (the latter servicing CPs that are "remote" to the ISP) that consider asymmetries in traffic aggregates; such SLAs are permitted under neutrality regulations. In particular, we showed that for our model, sufficiently high advertising revenue for the content provider incentivizes zero direct subscription costs to end-users. Finally, we considered a game between content providers, based on "managed" and commodity-Internet-access services, and found a condition on regulated side-payments for equal revenue at Nash equilibrium.

References

[1] E. Altman, P. Bernhard, S. Caron, G. Kesidis, J. Rojas-Mora, and S. Wong. A study of non-neutral networks under usage-based pricing. *Telecommunication Systems Journal Special Issue on Socio-economic Issues of Next Generation Networks*, 2011.

[2] T. Berners-Lee. Net Neutrality: This is serious. timbl's blog, http://dig.csail.mit.edu/breadcrumbs/node/144, June 2006.

[3] S. Caron, G. Kesidis, and E. Altman. Application neutrality and a paradox of side payments. In *Proc. ACM Re-Architecting the Internet (ReArch) Workshop, Philadelphia*, Nov. 2010.

[4] N. Economides and B. Hermalin. The strategic use of download limits by a monopoly platform. Working Paper 13-26, www.NETinst.org, Dec. 2013.

[5] R. Hahn and S. Wallsten. The economics of net neutrality. *Economists' Voice, The Berkeley Economic Press*, 3(6):1–7, 2006.

[6] P. Hande, M. Chiang, R. Calderbank, and S. Rangan. Network pricing and rate allocation with content provider participation. In *Proc. IEEE INFOCOM*, 2009.

[7] D. Kerr. France orders Internet provider to stop blocking Google ads. http://news.cnet.com/8301-1023_3-57562638-93/france-orders-internet-provider-to-stop-blocking-google-ads, Jan. 7, 2013.

[8] F. Kocak, G. Kesidis, T.-M. Pham, and S. Fdida. The effect of caching on a model of content and access provider revenues in information-centric networks. In *Proc. ASE/IEEE EconCom*, Washington, DC, Sept. 2013.

[9] R.T.B. Ma, D.-M. Chiu, J.C.S. Lui, V. Misra, and D. Rubenstein. Interconnecting eyeballs to content: A Shapley value perspective on ISP peering and settlement. In *Proc. Int'l Workshop on Economics of Networked Systems*, pages 61–66, 2008.

[10] R.T.B. Ma, D.-M. Chiu, J.C.S. Lui, V. Misra, and D. Rubenstein. On cooperative settlement between content, transit and eyeball Internet service providers. In *Proc. ACM CoNEXT*, 2008.

[11] J. Musacchio, G. Schwartz, and J. Walrand. A two-sided market analysis of provider investment incentives with an application to the net-neutrality issue. *Review of Network Economics*, 8(1), 2009.

[12] S. Sen, C. Joe-Wang, S. Ha, and M. Chiang. Incentivizing time-shifting of data: A survey of time-dependent pricing for Internet access. *IEEE Communications Magazine*, pages 91–99, Nov. 2012.

[13] A. Sherman. CBS deal ends Time Warner cable blackout ahead of NFL. http://www.bloomberg.com/news/2013-09-02/cbs-reaches-accord-to-end-blackout-on-time-warner-cable.html, Sept. 3, 2013.

[14] D. Weller and B. Woodcock. Bandwidth bottleneck: The hardware at the heart of the Internet is not fast enough. *IEEE Spectrum*, Jan. 2013.

[15] T. Wu. Network neutrality, broadband discrimination. *Journal of Telecommunications and High Technology Law*, 2:141, 2003.

[16] E. Wyatt and N. Cohen. Comcast and Netflix reach deal on service. http://www.nytimes.com/2014/02/24/business/media/comcast-and-netflix-reach-a-streaming-agreement.html?_r=0, Feb. 23, 2014.