Net Neutrality and Investment Incentives

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AT&T CEO Edward Whitacre: "[W]hat they would like to do is use my pipes free, but I ain’t going to let them do that because we have spent this capital and we have to have a return on it."
A coalition of content providers emerged in an effort to maintain the current status of non-discrimination regime.

The attempt to legislate the net neutrality regulation has failed in the Congress for now.

The issue is expected to continuously arise in the future.
An Example

- AP Report on October 19, 2007
  - Comcast interfered with users’ access to file sharing sites such as BitTorrent
  - Benign Traffic Management or Naked Discrimination?

- On July 11, 2008, Kevin Martin, Head of FCC
  - recommended that Comcast be punished for violating agency principles that guarantee customers open access to the Internet.
  - Seen as a Move Favoring Net Neutrality
What is Net Neutrality?

- There is no universally accepted definition of NN.
  - All packets are treated equally (first-come, first served).
  - Violations: Port blocking, Quality degradation, Access-tiering
    - Comcast interferes P2P file sharing site BitTorrent users' uploading
- In our paper, “Net Neutrality = No prioritization”
  - Without net neutrality regulation, it is possible to have a two-tiered Internet
    - The packets of paying content provider get the higher priority in delivery
    - Best effort for the rest. (No content blocking)
Pros and Cons

Claims of the proponents such as Google, Ebay, Yahoo, Microsoft, etc.

- From its inception...
- Absent regulation, “We are going to create a two-tier Internet, for the haves who can pay the price, and the have-nots who will be relegated to the Internet dirt road.” - Senator Olympia Sonowe
- End-to-end design principle
- Non-discrimination promotes innovations in Internet applications.

Claims of the opponents such as AT&T, Verizon, Comcast, etc.

- "The only way . . . to attract the . . . capital needed to build out these networks is to strike down governmental entry barriers and allow providers to realize profits" – Verizon
- Network operators have no incentive to invest in network capacity unless content providers who support bandwidth-intensive multi-media Internet traffic pay a premium.
Formal economic analysis addressing these issues has been scarce.
- Economides and Tag (2007)

Our focus is on Investment Incentives of ISPs and CPs
- Cheng et al. (2009)
- Valletti and Cambini (2005)
The Model of Net Neutrality

- A monopolistic ISP delivers two CPs’ contents to end consumers.
  - AT&T or Comcast / Yahoo and Google
- ISP sells its network connection to end users at access fee, $a$.
- With NN, CPs have free access to the network; without NN, first priority is assigned to one CP.
- CP earns a revenue stream $r$ from advertisers per consumer’s “click-through”
- CP’s service cost per consumer is assumed to be $c_i$, wlog, $0 \leq c_1 \leq c_2$.
- End users’ preference follows a standard Hotelling product differentiation model.
  - $t$: transport cost
  - fully covered market with a sufficiently high basic utility
The arrival rate of each consumer follows a Poisson distribution with $\lambda$.

In a neutral network, each consumer has the expected waiting time of

$$w = \frac{1}{\mu - \lambda}$$

- $\lambda$ denotes the gross arrival rate at the network (with the normalization of consumer mass to one)
- $\mu$ is the capacity of the network with $\mu > \lambda$. 

In the discriminatory network,

- A consumer who requests content designated to the first-priority class has an expected waiting time of

\[ w_1 = \frac{1}{\mu - \lambda_1} \quad (2) \]

where \( \lambda_1 \) is the total amount of traffic from consumers who request the content with first-priority.

- The consumer who requests the content without first priority faces the expected waiting time of

\[ w_2 = \frac{\mu}{\mu - \lambda} w_1 = \frac{\mu}{\mu - \lambda} \frac{1}{\mu - \lambda_1} \quad (3) \]
Preliminaries

- In a discriminatory network, a consumer experiences a longer delay by subscribing the basic service instead of the premium one, i.e.,

  \[ w_2 > w > w_1 \]  \text{for}  \mu > \lambda. \quad \text{Fact 1.}

- Proof) \( w_2 / w_1 = \mu / (\mu - \lambda) > 1. \)

- The quality difference measured in waiting costs becomes smaller as the network capacity increases, i.e.,

  \[ \frac{\partial}{\partial \mu} (w_2 - w_1) < 0. \]  \text{Fact 2.}

- Intuition: The marginal saving in waiting time for the fast-lane from capacity expansion decreases as the capacity level becomes high.
With net neutrality regulation, there are no priority classes in content delivery:

- The marginal consumer \( x^* \) satisfies
  
  \[
  v - \frac{1}{\mu - \lambda} - tx^* - a = v - \frac{1}{\mu - \lambda} - t(1 - x^*) - a,
  \]

  where consumers whose preferences are represented by \( x < x^* \) choose CP1 and those with \( x > x^* \) choose CP2.

- With two symmetrically positioned content providers, \( x^* = 1/2 \).

The ISP’s profit maximization problem is thus given by

\[
\max_a \pi_m = a \quad \text{s.t.} \quad v - \frac{1}{\mu - \lambda} - tx^* - a \geq 0.
\]

Then, we can derive the equilibrium network subscription fee and each content provider’s profit as

\[
\pi_m^* = a^* = v - \frac{1}{\mu - \lambda} - \frac{t}{2}; \quad \pi_i^* = \frac{r - c_i}{\lambda} \quad \text{for } i = 1, 2.
\]
Under discriminatory regime, the marginal consumer denoted by $\tilde{x}$ is defined as

$$v - \frac{1}{\mu - \tilde{x}\lambda} - t\tilde{x} - a = v - \frac{\mu}{\mu - \lambda} \frac{1}{\mu - \tilde{x}\lambda} - t(1 - \tilde{x}) - a. \quad (7)$$

The content provider with first-priority has a larger market share than the one without it, i.e., $\tilde{x} \geq x^* = 1/2$.

If $\mu > \frac{3\lambda}{2}$, an interior and stable equilibrium:
Lemma

If $\mu > \frac{3\lambda}{2}$, we get $\frac{d\bar{x}}{d\mu} < 0$.

Intuition: an increased capacity of ISP makes congestion less important and reduces the relative quality differential (i.e., waiting costs) across the two CPs.
The ISP’s profit is given by

$$\max_a \tilde{\pi}_m = a + f \quad \text{s.t.} \quad v - \frac{1}{\mu - \tilde{x}\lambda} - t\tilde{x} - a \geq 0,$$

(8)

where $f$ denotes the ISP’s revenue from priority assignment.

More specifically, let $\theta$ ($0 \leq \theta \leq 1$) denote the ISP’s bargaining power. The price of the first priority is given by

$$f|_{\theta \in [0,1]} = \theta (r - c_1)(2\tilde{x} - 1)\lambda + (1 - \theta)(r - c_2)(2\tilde{x} - 1)\lambda \quad (9)$$

$$= [r - \theta c_1 - (1 - \theta)c_2] (2\tilde{x} - 1)\lambda$$

ISP’s take-it-or-leave-it offer: $\theta = 1$ with $f|_{\theta=1} = (r - c_1)(2\tilde{x} - 1)\lambda$.

the first-price bid auction: $\theta = 0$ with $f|_{\theta=0} = (r - c_2)(2\tilde{x} - 1)\lambda$.

All the intermediate cases are captured by some $\theta \in (0,1)$.

Note $\frac{\partial f}{\partial \theta} = (c_2 - c_1)(2\tilde{x} - 1)\lambda \geq 0$. 
The ISP’s profit in a discriminatory network thus is given by

\[
\tilde{\pi}_m^* = \left( v - \frac{1}{\mu - \bar{x}\lambda} - t\bar{x} \right) + \left[ r - \theta c_1 - (1 - \theta)c_2 \right] (2\bar{x} - 1) \lambda \tag{10}
\]

Each content provider’s profit is respectively given by

\[
\tilde{\pi}_1^* = (r - c_1)\bar{x}\lambda - \left[ r - \theta c_1 - (1 - \theta)c_2 \right] (2\bar{x} - 1) \lambda \tag{12}
\]

\[
\tilde{\pi}_2^* = (r - c_2)(1 - \bar{x})\lambda
\]
We find the following potential trade-off: without net neutrality the ISP earns less profit from consumers due to the decreased network access fee ($a$), but gains from trading the priority to the low-cost content provider ($f$).

**Lemma**

The network access fee in discriminatory network is lower than that in neutral network, i.e., $\tilde{a} < a^*$.

In the absence of regulation, the ISP will choose to introduce the premium service when its gain from prioritization is sufficiently high.
Proposition 1.

(a) \( \tilde{\pi}_m^* \geq \pi_m^* \) iff \( r \geq \bar{r} \) where

\[
\bar{r} \equiv \theta c_1 + (1 - \theta) c_2 + \frac{t}{2\lambda} + \frac{1}{(2\bar{r}-1)\lambda} \left( \frac{1}{\mu-\bar{r} \lambda} - \frac{1}{\mu-\lambda} \right);
\]

- **Part (a)**
  - The ISP’s profit is higher with a discriminatory network if the advertising revenue is sufficiently high.
  - Intuition: For a sufficiently high \( r \), market share is more important and CPs compete more aggressively to get the first priority in a discriminatory network. As a result, the ISP receives a higher price for the premium service, which can outweigh any potential loss in access fees from end users.
  - Unless \( r \) is sufficiently high, the ISP will endogenously choose the equal treatment of both content providers even though the net neutrality is *not* required.
The low-cost content provider who obtains the first priority can have a higher payoff in the discriminatory regime if the cost differential is sufficiently large.

In contrast, the high-cost content provider is always worse-off from the introduction of priority classes.

The possibility that both content providers may engage in a Prisoners’ dilemma type of game to receive the first priority, if \( r > \max[\bar{r}, c_2 + (c_2 - c_1)(1 - 2\theta)] \).
(d) Aggregate consumer welfare increases without net neutrality regulation.

Proof) Notice that the marginal consumers in the neutral network and the discriminatory network are located at \( x^* = 1/2 \) and \( \tilde{x}(> 1/2) \), respectively, and they receive zero payoffs. This implies that
\[
CS = 2 \int_0^{1/2} txdx \quad \text{and} \quad \tilde{CS} = \int_0^{\tilde{x}} txdx + \int_{1-\tilde{x}}^{1/2} txdx.
\]
Therefore,
\[
\tilde{CS} - CS = \int_{1/2}^{\tilde{x}} txdx - \int_{1-\tilde{x}}^{1/2} txdx > 0.
\]
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3. **Total Delay Costs:** Invariant! The total expected waiting costs are the same in both neutral and discriminatory regimes.

If the two CPs are symmetric in their service cost, the short-run social welfare is higher under net neutrality regulation.
ISPs such as Verizon, Comcast, and AT&T oppose network neutrality regulation claiming that such regulation would discourage their investment incentives in broadband networks.

- Rationale for their claim: *Free-riders’ problem*
- We examine the validity of their claim in this paper by the comparison of optimal investments across different regimes.

Denote $\Phi(\mu)$ to be the cost associated with the capacity level of $\mu$ with $\Phi' \geq 0$ and $\Phi'' \geq 0$.

Then, the ISP’s choice of optimal investment will be determined at the point where the marginal benefit and the marginal cost with respect to $\mu$ are equal to each other, i.e., $d\pi_m / d\mu = \Phi'(\mu)$ in the neutral network and $d\tilde{\pi}_m / d\mu = \Phi'(\mu)$ in the discriminatory network.
Long Run Analysis with Investment Incentives

\[
\frac{d\tilde{\pi}_m}{d\mu} - \frac{d\pi_m}{d\mu} = \left( \frac{d\tilde{a}}{d\mu} - \frac{da}{d\mu} \right) + \frac{df}{d\mu}
\]

\[
= \left[ \frac{1}{(\mu - \tilde{x}\lambda)^2} \left( 1 - \lambda \frac{d\tilde{x}}{d\mu} \right) - t \frac{d\tilde{x}}{d\mu} - \frac{1}{(\mu - \lambda)^2} \right]
\]

Changes in the Effect of Capacity Expansion on End User Access Fee with Discrimination

\[
+ 2 \left[ r - \theta c_1 - (1 - \theta) c_2 \right] \lambda \frac{d\tilde{x}}{d\mu}
\]

The Effect of Capacity Expansion on the Sale Price of Priority Right
Network access fee effect (?)

- In the network with net neutrality, capacity expansion speeds up the delivery of content uniformly, while in the discriminatory network it affects the delivery speed of content asymmetrically across content providers.

Rent extraction effect (-)

- Congestion problem becomes less severe for a higher capacity level
- The ISP’s rent from the allocation of priority classes also decreases, which in turn leads to a weaker investment incentive under discriminatory regime.
Proponents of net neutrality regulation maintain that killer applications have been developed at the ‘edges’ of the network by users, not by the ‘core’ of the network operators.

There is a typical concern about the so-called hold-up problem when part of return from one party's relationship-specific investments is ex post expropriable by his trading partner.

It is an interesting question if the ISP would have the incentive to commit to net neutrality to maintain the content providers’ incentives to invest.
Let us assume that a lower marginal cost is achieved at the expense of a higher sunk cost.

An irreversible investment in cost-reducing R&D is characterized by a twice differentiable function of $\Psi(\Delta_i)$ with $\Psi' > 0$, $\Psi'' > 0$, where $\Delta_i$ denotes the magnitude of the cost reduction from investment, i.e.,

$$\Delta_i = \bar{c}_i - c_i.$$ 

We can think of $\bar{c}_i$ as the current best technology that is freely available to content provider $i$ and $c_i$ as the post-investment cost level for $i = 1, 2$.

In neutral network, each content provider’s optimal investment is determined by

$$\Psi'(\Delta_i^*) = \frac{\lambda}{2} \quad \text{for } i = 1, 2. \quad (14)$$

In discriminatory network,

$$\Psi'(\tilde{\Delta}_1^*) = (\tilde{x} - \theta(2\tilde{x} - 1)) \lambda \quad \text{and} \quad \Psi'(\tilde{\Delta}_2^*) = (1 - \tilde{x})\lambda. \quad (15)$$
By the comparison of optimal investments under neutrality network with those under discriminatory one, we earn following results.

**Proposition**

*Both the low-cost and the high-cost content providers will choose a technology with a higher marginal cost under the discriminatory network than they will choose under the neutrality network i.e., \( \tilde{\Delta}_1^* < \Delta_1^* \) and \( \tilde{\Delta}_2^* < \Delta_2^* \) if and only if the ISP’s expropriation is high enough to the extent of \( \theta > 1/2 \). Otherwise (\( 0 \leq \theta \leq 1/2 \)), we have \( \tilde{\Delta}_1^* \geq \Delta_1^* \) and \( \tilde{\Delta}_2^* < \Delta_2^* \).*

- Implication: the ISP *may* have the incentive to commit to net neutrality to maintain the content providers’ innovation incentives.
Further Research Topics

- **Heterogeneity in Delay Costs across Content**
  - Email vs video/audio or VoIP applications
  - Point of interest: the imposition of net neutrality requirements impedes the development of time-sensitive applications such as remote medical supervision?

- **Possibility of Quality Degradation**
  - Point of interest: the ISP wants to degrade the quality of non-priority packet (deliberately slow down the delivery speed of content) for the purpose of extracting rent more effectively and restore incentives to invest in the discriminatory regime?

- **Integration/Strategic Alliance of ISPs and CPs**
  - Point of interest: if AT&T would have an incentive to give its partner Yahoo site preferential treatment over competing sites such as Google in the absence of net neutrality regulations?
This paper provides an economic analysis of the net neutrality regulation. In particular, our analysis focuses on the effects of net neutrality regulation on the investment incentives of ISPs and CPs as well as on social welfare.

We identified key effects and intuitions in the assessment of net neutrality regulations. By doing so, we inform policy-makers who need to act with care and make an informed decision based on rigorous analysis to provide a market environment in which the right investment signals are given.

We propose further research topics in order to expedite more research.