Network Neutrality on the Internet

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Network industries: two-sided pricing

- **Two-sided pricing**: network firms can set price(s) on either or both sides of a market

Examples (vertically integrated):
- Adobe Acrobat and Adobe Reader
- Advertisers and users (in Internet search engines, Yellow Pages, newspapers)
- Originating and terminating charges in (old) AT&T monopoly

Examples (vertically disintegrated, components made by different companies):
- Computer clients and servers
- Operating systems and applications
- Game platform/console and games (software)
- Authors and readers in academic journals
- Internet content providers and Internet users
Two-sided Pricing in Vertically Disintegrated Setups

- Who pays whom?
  - Computer OSs subsidize applications
  - Game platforms collect from software developers
  - In credit cards, the Visa and MasterCard networks have set a fixed percentage discount (price) between issuer and acquirer banks (price fixing?)
  - Issuers may pay users since they collect from merchants
  - Newspapers could go from positive to zero price
  - In many academic journals readers pay but opposite also possible (authors pay)

- Should we apply regulation? How?
  - When regulation is possible on both sides of the market
  - When regulation is possible on one side only
    - with cost-based pricing on the other side
    - with monopoly pricing on the other side
    - with duopoly pricing on the other side
Two-sided Pricing in General
When There Are Two Network Effects

Content Providers

Platform (ISP)

Consumers

s

R

p
Two-sided Pricing in the Absence of Net Neutrality

Disney
Google

Internet Backbone

ISP

$R$: subscription price

Residential Customers

$s$: AT&T’s fee to content providers or many fees $s_1, s_2, \ldots, s_n$

$p$
How concerned are you about Internet upstarts like Google, MSN, Vonage, and others?

“How do you think they're going to get to customers? Through a broadband pipe. Cable companies have them. We have them. Now what 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. So there's going to have to be some mechanism for these people who use these pipes to pay for the portion they're using. Why should they be allowed to use my pipes?

The Internet can't be free in that sense, because we and the cable companies have made an investment and for a Google or Yahoo! or Vonage or anybody to expect to use these pipes [for] free is nuts!”
But Both Sides Pay for “Transit” on the Internet

- All hosts on the Internet pay according to bandwidth use: there is no “free lunch” on the Internet
- AT&T, Verizon, and others are paid by ISPs according to bandwidth use
- Actually Internet backbones are paid twice for any transmission, by the originator of traffic and by the terminator of traffic (through their respective ISPs)
US Lagging in Broadband

OECD Broadband subscribers per 100 inhabitants, by technology, June 2009

Source: OECD
US Lags Behind Poorer Countries

OECD broadband penetration and GDP per capita

Source: OECD
The Internet Was Based

- on three basic separate levels of functions of the network:
  - (i) the hardware/electronics level of the physical network
  - (ii) the (logical) network level where basic communication and interoperability is established
  - (iii) the applications/services level

- The Internet separates the network interoperability level from the applications/services level

- Unlike earlier centralized digital electronic communications networks, such as CompuServe, AT&T Mail, Prodigy, and early AOL, the Internet allows a large variety of applications and services to be run “at the edge” of the network and not centrally
So What Do AT&T, Verizon and Cable TV Companies Want?

- Abolish the regime of “net neutrality”
- Set up pricing schedules where, besides the basic service for transmission of bits, there will be additional charges by the broadband Internet access provider applied to the originating party (such as Google, Yahoo, or MSN).
- The new pricing model without net neutrality would be closer to the traditional pre-Internet telecommunications model where customers pay per service.
- This would also be a very sharp departure from the way the Internet has been designed and run since its inception.
Varying Levels Of “Net Neutrality,” from Strictest to Weakest

Referring to pricing to the “other side” of the consumer market (that is, to content and applications providers):

1. Absolute non-discrimination: no quality of service variations offered for money or for free

2. Varying quality of service offered according to type of info. packet but no fees are charged

3. Tiered service allowed but each tier is offered at the same price to all; no exclusivity or identity-based discrimination

4. Identity-based discrimination allowed

5. Exclusivity allowed
Barack Obama strongly supports the principle of network neutrality to preserve the benefits of open competition on the Internet. ... Because most Americans only have a choice of only one or two broadband carriers, carriers are tempted to impose a toll charge on content and services, discriminating against websites that are unwilling to pay for equal treatment. This could create a two tier Internet in which websites with the best relationships with network providers can get the fastest access to consumers, while all competing websites remain in a slower lane.

Such a result would threaten innovation, the open tradition and architecture of the Internet, and competition among content and backbone providers. It would also threaten the equality of speech through which the Internet has begun to transform American political and cultural discourse.

Barack Obama supports the basic principle that network providers should not be allowed to charge fees to privilege the content or applications of some web sites and Internet applications over others.

This principle will ensure that the new competitors, especially small or non-profit speakers, have the same opportunity as incumbents to innovate on the Internet and to reach large audiences.
FCC’s NPRM (Oct. 2009) (1): “Subject to reasonable network management, a provider of broadband Internet access service may not:

1. prevent any of its users from sending or receiving the lawful content of the user’s choice over the Internet.
2. prevent any of its users from running the lawful applications or using the lawful services of the user’s choice.
3. prevent any of its users from connecting to and using on its network the user’s choice of lawful devices that do not harm the network.
4. deprive any of its users of the user’s entitlement to competition among network providers, application providers, service providers, and content providers.”
FCC’s NPRM (2): “Subject to reasonable network management, a provider of broadband Internet access service must treat lawful content, applications, and services in a nondiscriminatory manner

- We understand the term “nondiscriminatory” to mean that a broadband Internet access service provider may not charge a content, application, or service provider for enhanced or prioritized access to the subscribers of the broadband Internet access service provider ...
- We propose that this rule would not prevent a broadband Internet access service provider from charging subscribers different prices for different services.”
FCC Rule (December 2010)

1. **Transparency**: Fixed and mobile broadband providers must disclose the network management practices, performance characteristics, and terms and conditions of their broadband services.

2. **No blocking**: Fixed broadband providers may not block lawful content, applications, services, or non-harmful devices; mobile broadband providers may not block lawful websites, or block applications that compete with their voice or video telephony services.

3. **No unreasonable discrimination**: Fixed broadband providers may not unreasonably discriminate in transmitting lawful network traffic.

Even though this regulation is weak, Verizon sued to stop it.
National Regulatory Authorities are required to promote “the ability of end-users to access and distribute information or run applications and services of their choice”.

National Regulatory Authorities, after consulting the Commission, can set minimum quality of service requirements.

Strong transparency to ensure consumers understand and get what they pay for.
Residential ISPs have market power; also claim local congestion

Assuming no congestion, Economides and Tag (2012) showed that introducing a positive price to content providers is typically welfare-inferior to NN


- ISPs claim that NN is not optimal with congestion

- Issue addressed in Economides and Hermalin (2012), forthcoming in RAND
Homogeneous consumers
Content/applications providers are indexed by $\theta$ (considering higher $\theta$ to be more time sensitive)
Provider $\theta$ provides $x(\theta)$ info. packets
Total bandwidth $B$, which may be sub-divided in dedicated “pipes” $B_1, B_2, \ldots, B_J$
Congestion implies time delay for provider $\theta$ in pipe $B_\theta$

$$t(\Theta) \equiv \frac{\int_\Theta X(\theta)dF(\theta)}{B_\Theta}$$
Household utility

\[ U = y + \int_{\hat{\theta}}^{\bar{\theta}} \left( \int_0^x m \left( \frac{x}{\alpha(\tau(\theta), \theta)} \right) dx \right) dF(\theta) \]

- \( y \): leftover money
- \( m(.) \): “adjusted” marginal utility of info. packets, \( m > 0 \), \( m' < 0 \)
- \( \alpha(\tau(\theta), \theta) \) reflects the extent that consumers care about time delay of packets of type \( \theta \)
- high \( \alpha \) is equivalent to the consumer receiving fewer packets \( x \), which means higher marginal utility
- \( \alpha \) decreasing in delay \( \tau \), so \( m \) decreasing in \( \tau \), \( \partial \alpha / \partial \tau < 0 \)
- Higher \( \theta \) content more time sensitive: \( \partial^2 \alpha / \partial \tau \partial \theta < 0 \)
Demand and content provider’s profits

\[ x(p, \theta) = \alpha(\tau(\theta), \theta) m^{-1}(p) = \alpha(\tau(\theta), \theta) \omega(p) \]

\[ \Pi(\theta) = (q + p - c)x(p, \theta) - s \]

- where \( q \) is advertising revenue rate, \( p \) is payment by the consumer, \( c \) is marginal cost, and \( s \) is payment by a content provider to the ISP
- Profit maximization is equivalent to maximizing

\[ \max_p (q + p - c)\omega(p) \]

Let \( p^* \) be the maximizer and \( \pi \) be the maximum. Then, the maximized profits of provider \( \theta \) plus payments to the ISP are proportional to the content sales quantity

\[ \Pi(\theta) = \alpha(\tau(\theta), \theta)\pi - s = x(p^*, \theta)\pi/\omega(p^*) - s \]
Consumers surplus and welfare

\[ cs(\theta) = \int_{p^*}^{\infty} x(p, \theta) dp = \alpha(\tau(\theta), \theta) \int_{p^*}^{\infty} \omega(p) dp \equiv \alpha(\tau(\theta), \theta) \sigma \]

\[ W = \int_{\theta}^{\bar{\theta}} \alpha(\tau(\theta), \theta)(\pi + \sigma)dF(\theta) = \frac{\pi + \sigma}{\omega(p^*)} X \]

- Welfare is proportional to total content sales \( X \)
- For each content provider \( \theta \), profits are increasing in its sales \( x(\theta) \)
  \[ \Pi(\theta) = x(p^*, \theta) \pi/\omega(p^*) - s \]
A bandwidth allocation is welfare superior if it carries more content

- Consider divisions of bandwidth in lanes
- **Proposition 1.** Given two alternative divisions of the total bandwidth, one is welfare superior to the other if and only if it results in more content being carried in equilibrium than the other.

- **Corollary 1.** Network neutrality is welfare superior (at least weakly) to any division of the bandwidth if no division of the bandwidth leads to more content being sent in equilibrium.
Amount of content carried is a “sufficient statistic” for welfare

and how bandwidth is allocated to content does not matter

- Content is analogous to income, and it has the maximum positive effect on welfare when it is allocated as the consumer sees fit without restrictions
  - Restrictions (special lanes etc.) in its allocation restrict welfare

- Reminiscent of Varian (1985,9) showing that third degree price discrimination increase welfare vis-a-vis uniform pricing only if it increases the total amount of goods sold
Proposition 2. Suppose the ISP provides a common class of service, but excludes a positive measure of content providers. In the resulting equilibrium, welfare is less than it would be were no content providers excluded.
Dividing the bandwidth increases or decreases total content sent?

- Which (if any) packets should be sent faster?
- Maximize $W$ subject to bandwidth constraint
- Comparative statics on the maximized $W^*$ define the optimal delay $\tau (\theta)$
- $\tau (\theta)$ increasing (decreasing) in $\theta$ if the cross partial derivative of $W^*(\tau (\theta), \theta)$ or $\log(\alpha(\tau (\theta), \theta))$ or $\log(X^*)$ with respect to $\tau$ and $\theta$ is positive (negative)
- **If cross partial zero, network neutrality is optimal**
- Define the elasticity of content sales wrt $\tau$

$$\epsilon(\tau, \theta) \equiv -\frac{\partial \log (\alpha(\tau, \theta)\omega(p^*))}{\partial \log(\tau)} = -\frac{\partial \log (\alpha(\tau, \theta))}{\partial \log(\tau)} = -\tau \frac{\partial \log (\alpha(\tau, \theta))}{\partial \tau}$$

- Cross partial of $W^*$ wrt $\tau$, $\theta$ is negative (and therefore higher $\theta$ content is prioritized) when the partial wrt to $\theta$ of the elasticity of content sales wrt $\tau$ is positive
Intuition

- Assume originally
  - same time delivery of $\theta$ and $\theta'$
  - higher time-elasticity of demand wrt time delay for $\theta$ rather than $\theta'$
- Then shifting content from $\theta'$ to $\theta$ will increase content traded
Network neutrality is optimal when

\[ \alpha(\tau, \theta) = \gamma(\tau)v(\theta) \]

which means that the (lack of) preference for delay \( \tau \) is “independent” of content type \( \theta \)
Elasticity of demand of content wrt transmission time:

\[ \epsilon(\tau, \theta) \equiv -\frac{\partial \log (\alpha(\tau, \theta) \omega(p^*) \lambda(\theta))}{\partial \log(\tau)} = -\frac{\partial \log (\alpha(\tau, \theta))}{\partial \log(\tau)} = -\tau \frac{\partial \log (\alpha(\tau, \theta))}{\partial \tau} \]

- **Proposition 3.** [Assume \( \theta < \theta' \)] Suppose the elasticity of content demand \( \epsilon(\tau, \theta) \) with respect to transmission time is monotone in \( \theta \), holding time constant. Then if, for all \( \tau \), the elasticity of demand for content \( \theta \) with respect to transmission time exceeds that of content \( \theta' \) (i.e., \( \epsilon(\tau, \theta) > \epsilon(\tau, \theta') \) all \( \tau \)), a welfare-maximizing allocation of bandwidth across content providers is such that the equilibrium transmission time for \( \theta \) content is shorter than for \( \theta' \) content (i.e., \( \tau(\theta) < \tau(\theta') \)). If the elasticity of demand with respect to transmission time is invariant with respect to content, then network neutrality is welfare maximizing.
If ISP charges content providers, it may eliminate low-θ providers.

Proposition 5. Let the adjustment function α be twice differentiable in its arguments. Suppose the elasticity of demand with respect to transmission time is non-increasing in content type holding time constant (i.e., 0 ≥ ∂ε(τ, θ)/∂θ for all τ and θ). Then any feasible price discrimination (tiered service) scheme that the ISP can implement vis-a-vis the content providers will be welfare inferior to network neutrality.
Does the ISP want NN?

- **Proposition 7.** Suppose the adjustment function, \( \alpha(\tau, \theta) = \gamma(\tau)v(\theta), \gamma' < 0, v' > 0, \) is multiplicatively separable in delay time and type with both functions differentiable. Then the residential ISP will strictly prefer not to implement network neutrality.

- **Corollary 4.** The ISP will choose prices that do not result in NN.
Dynamics

- Allow the ISP to expand bandwidth
- An unconstrained ISP may install more bandwidth
- More bandwidth alleviates some of the static distortion
- For example, for \( \alpha(\tau, \theta) = \theta / \tau \), NN is better for welfare when \( \sigma / \pi > 1.32 \)
- Where \( \sigma \) as the per output unit CS (similar to \( \pi \), the per output unit ISP profits)
Extensions

- ISP pricing per unit and not in lump sum – no significant difference
- Heterogeneous households
- Content providers with varying margins
- Generalization of the utility function
- Other utility functions
- Main results go through
Conclusions

- Under reasonable assumptions, welfare increases in the total amount of content carried.
- Even in the presence of congestion, NN can maximize welfare:
  - if the elasticity of demand with respect to transmission time is invariant with respect to content type.
  - But depending on that elasticity, to maximize welfare you may want to prioritize or slow down content of high immediacy desire.
- Killing NN can increase bandwidth investment and reduce the static allocative distortion.