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Broadband User Discrimination and the Net Neutrality Debate

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Broadband User Discrimination and the Net Neutrality Debate

• Recent industrial developments:
  – Comcast throttled P2P traffic
  – Time Warner Cable has recently started experiments
    • charge Internet customers based on how much Web data they consume
    • or charge a premium to the heaviest broadband users
  – AT&T performed similar experiments
  – Federal appeals court favors Comcast in F.C.C. ‘Net Neutrality’ Ruling on April 6, 2010
Literature on Net Neutrality

• Economides and Tag (2007)
  – examine the effect of two-sided pricing with provider discrimination
  – net neutrality regulation increases total industry surplus in the presence of a monopoly ISP or in the duopoly setting

• Cheng, Bandyopadhyay, and Guo (2007)
  – finds that ISP either over-invests or under-invests in infrastructure capacity when net neutrality is abolished

• Lee and Wu (2009)
  – While the net neutrality debate has many aspects, in this paper we focus on one crucial issue: the de facto rule prohibiting consumers’ ISPs from charging fees to content providers for access to their customer base.
Schematic of the model

Internet Backbone

Content Providers

Broadband Service Provider at local loop

Charge content providers

Charge consumers

End Consumers

$\lambda_H$

$\lambda_L$
Research Questions

• From a broadband service provider (BSP)’s perspective: Would a BSP gain by employing different pricing and/or packet prioritization strategies?

• From a social planner’s perspective: Would abolishing net neutrality on the “demand” side result in lower consumer surplus or social welfare?
The Model
The Model – BSP

• A monopolist BSP
  – Pricing
    • Uniform fixed fee ($F$) to all consumers
    • Different fixed fees ($F_H$ and $F_L$) to different types of consumers
    • Two-part tariff: fixed fee ($F$) + usage-based fee ($p$)
  – Capacity $\mu$
The Model – Consumers

• Heterogeneous usage patterns

<table>
<thead>
<tr>
<th>User Type</th>
<th>Valuation for data consumption</th>
<th>Data usage</th>
<th>Fraction of the entire consumer base</th>
</tr>
</thead>
<tbody>
<tr>
<td>H (heavy)</td>
<td>$V_H$</td>
<td>$\lambda_H$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>L (light)</td>
<td>$V_L$</td>
<td>$\lambda_L$</td>
<td>$1 - \alpha$</td>
</tr>
</tbody>
</table>

• Assume $V_H > V_L$ and $\lambda_H > \lambda_L$. 
The Model – Consumers

• Consumers’ utility function

\[ u_i = \begin{cases} 
V_i - d \cdot w_i - F, & \text{if the BSP charges a uniform fixed fee} \\
V_i - d \cdot w_i - F_i, & \text{if the BSP charges differential fixed fees} \\
V_i - d \cdot w_i - F - \lambda_i p, & \text{if the BSP charges a two-part tariff} 
\end{cases} \]

where \( i = H, L \)

\( w_i = \) Expected time in the queueing system

\( d = \) Consumers’ delay cost parameter
The Model – Traffic Prioritization

• Same priority
  \[ w_i = \frac{1}{\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L}, \quad i = H \text{ or } L \]

• Higher priority for H and lower priority for L
  \[ w_H = \frac{1}{\mu - \alpha \lambda_H}, \quad w_L = \frac{\mu}{(\mu - \alpha \lambda_H)\left[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L\right]} \]

• Lower priority for H and higher priority for L
  \[ w_H = \frac{\mu}{\left[\mu - (1 - \alpha) \lambda_L\right]\left[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L\right]}, \quad w_L = \frac{1}{\mu - (1 - \alpha) \lambda_L} \]
Forms of User Discrimination

<table>
<thead>
<tr>
<th>Traffic Prioritizing</th>
<th>Net Neutrality</th>
<th>No Net Neutrality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pricing</td>
<td>No Traffic Prioritization</td>
<td>Traffic Prioritization</td>
</tr>
<tr>
<td>Uniform fixed fee</td>
<td>Option NN1</td>
<td>Option NNN1</td>
</tr>
<tr>
<td>Differential fixed fees</td>
<td>Option NN2</td>
<td>Option NNN2</td>
</tr>
<tr>
<td>Two-part tariff</td>
<td>Option NN3</td>
<td>Option NNN3</td>
</tr>
</tbody>
</table>
Six Options of User Discrimination
Option NN1

- **Formulation**

  \[
  \max_{F_{NN1}} \pi_{NN1} = F_{NN1}
  \]

  \[
  \text{s.t. } V_H - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} - F_{NN1} \geq 0 \quad (i)
  \]

  \[
  V_L - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} - F_{NN1} \geq 0 \quad (ii)
  \]

- **Results**

  \[
  \pi^*_{NN1} = F^*_{NN1} = V_L - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L}
  \]
Option NN2

• Formulation

\[
\max_{F_{NN2_H}, F_{NN2_L}} \pi_{NN2} = \alpha F_{NN2_H} + (1-\alpha) F_{NN2_L}
\]

s.t. \[
V_H - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} - F_{NN2_H} \geq 0 \quad (i)
\]

\[
V_L - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} - F_{NN2_L} \geq 0 \quad (ii)
\]

• Results

\[
F_{NN2_H}^* = V_H - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} \quad \text{and} \quad F_{NN2_L}^* = V_L - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L}
\]
Option NN3

- **Formulation**

\[ \max_{F_{NN3}, P_{NN3}} \pi_{NN3} = F_{NN3} + \left[ \alpha \lambda_H + (1-\alpha) \lambda_L \right] p_{NN3} \]

s.t. \[
V_H - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} - F_{NN3} - \lambda_H p_{NN3} \geq 0 \quad (i) \]

\[
V_L - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} - F_{NN3} - \lambda_L p_{NN3} \geq 0 \quad (ii) \]

- **Results**

\[
F_{NN3-1}^* = \frac{\lambda_H V_L - \lambda_L V_H}{\lambda_H - \lambda_L} - \frac{d}{\mu - \alpha \lambda_H - (1-\alpha) \lambda_L} \]

\[
p_{NN3-1}^* = \frac{V_H - V_L}{\lambda_H - \lambda_L} \]
Option NNN1

- **Formulation**

\[
\max_{F_{NNN1}} \pi_{NNN1} = F_{NNN1}
\]

\[
\text{s.t. } V_H - \frac{d \mu}{\left[\mu - (1-\alpha)\lambda_L\right]\left[\mu - \alpha\lambda_H - (1-\alpha)\lambda_L\right]} - F_{NNN1} \geq 0 \quad (i)
\]

\[
V_L - \frac{d}{\mu - (1-\alpha)\lambda_L} - F_{NNN1} \geq 0 \quad (ii)
\]

- **Results**

<table>
<thead>
<tr>
<th>Case NNN1_1:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{NNN1_1}^* = V_H - \frac{d \mu}{\left[\mu - (1-\alpha)\lambda_L\right]\left[\mu - \alpha\lambda_H - (1-\alpha)\lambda_L\right]} )</td>
</tr>
<tr>
<td>( \pi_{NNN1_1}^* = V_H - \frac{d \mu}{\left[\mu - (1-\alpha)\lambda_L\right]\left[\mu - \alpha\lambda_H - (1-\alpha)\lambda_L\right]} )</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Case NNN1_2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{NNN1_2}^* = V_L - \frac{d}{\mu - (1-\alpha)\lambda_L} )</td>
</tr>
<tr>
<td>( \pi_{NNN1_2}^* = V_L - \frac{d}{\mu - (1-\alpha)\lambda_L} )</td>
</tr>
</tbody>
</table>
Option NNN2

- **Formulation**

\[
\max_{F_{\text{NNN2}_H}, F_{\text{NNN2}_L}} \pi_{\text{NNN2}} = \alpha F_{\text{NNN2}_H} + (1-\alpha) F_{\text{NNN2}_L}
\]

s.t. \[ V_H - \frac{d}{\mu - \alpha \lambda_H} - F_{\text{NNN2}_H} \geq 0 \] (i)

\[ V_L - \frac{d \mu}{(\mu - \alpha \lambda_H)\left[\mu - \alpha \lambda_H - (1-\alpha) \lambda_L\right]} - F_{\text{NNN2}_L} \geq 0 \] (ii)

- **Result**

\[ F^*_{\text{NNN2}_H} = V_H - \frac{d}{\mu - \alpha \lambda_H} \]

\[ F^*_{\text{NNN2}_L} = V_L - \frac{d \mu}{(\mu - \alpha \lambda_H)\left[\mu - \alpha \lambda_H - (1-\alpha) \lambda_L\right]} \]
Option NNN3

- Formulation

\[
\begin{align*}
\max_{F_{\text{NNN3}}, P_{\text{NNN3}}} & \quad \pi_{\text{NNN3}} = F_{\text{NNN3}} + \alpha \lambda_H p_{\text{NNN3}} \\
\text{s.t.} & \quad V_H - \frac{d}{\mu - \alpha \lambda_H} - F_{\text{NNN3}} - \lambda_H p_{\text{NNN3}} \geq 0 \\
& \quad V_L - \frac{d \mu}{(\mu - \alpha \lambda_H)[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L]} - F_{\text{NNN3}} \geq 0 \\
& \quad V_L - \frac{d \mu}{(\mu - \alpha \lambda_H)[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L]} - F_{\text{NNN3}} \geq V_L - \frac{d}{\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L} - F_{\text{NNN3}} - \lambda_L p_{\text{NNN3}}
\end{align*}
\]
Option NNN3

- Results

**Case NNN3_1:**

\[ F_{\text{NNN3}_1} = V_L - \frac{d \mu}{(\mu - \alpha \lambda_H)\left[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L\right]} \]

\[ p_{\text{NNN3}_1} = \frac{1}{\lambda_H} \left\{ (V_H - V_L) + \frac{d \mu}{(\mu - \alpha \lambda_H)\left[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L\right]} - \frac{d}{\mu - \alpha \lambda_H} \right\} \]

**Case NNN3_2:**

\[ F_{\text{NNN3}_2} = V_H - \frac{d}{\mu - \alpha \lambda_H} - \frac{d \mu}{\lambda_L \left[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L\right]} - \frac{d}{\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L} \]

\[ p_{\text{NNN3}_2} = \frac{1}{\lambda_L} \left\{ \frac{d \mu}{(\mu - \alpha \lambda_H)\left[\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L\right]} - \frac{d}{\mu - \alpha \lambda_H - (1 - \alpha) \lambda_L} \right\} \]
The BSP’s Choices
The BSP’s preference for pricing structure under net neutrality
(choice among three options NN1, NN2, NN3)

• Proposition 1: Under net neutrality, the BSP prefers a differentiated fixed fee or a two-part tariff.
The BSP’s preference for pricing structure under no net neutrality
(choice among three options NNN1, NNN2, NNN3)

• Proposition 2: Under no net neutrality, there are two potential preferred pricing structures for the BSP: NNN1 or NNN2, depending on the parameter values.
The BSP’s overall preference for pricing structure considering all six options

• Proposition 3: Overall there are three potential preferred pricing structures for the BSP: NN2, NN3 or NNN1, depending on the parameter values.
The BSP’s choice for user discrimination

(choice among all six options)

Proposition 3:

NN2 or NN3: shaded area
NNN1: unshaded area
The Social Planner’s Preferences
Social Welfare

• Definition

\[ SW = \pi + CS \]
\[ = \left[ \alpha \cdot \text{Payment}_H + (1-\alpha) \cdot \text{Payment}_L \right] \]
\[ + \left[ \alpha (V_H - d \cdot w_H - \text{Payment}_H) + (1-\alpha) (V_L - d \cdot w_L - \text{Payment}_L) \right] \]
\[ = \alpha (V_H - d \cdot w_H) + (1-\alpha) (V_L - d \cdot w_L) \]
The social planner’s preference for pricing structure under net neutrality (NN1, NN2, NN3)

• Proposition 4:

When net neutrality is in place, social welfare is the same for a uniform fixed fee, different fixed fees, and a two-part tariff.

i.e., $SW_{NN1} = SW_{NN2} = SW_{NN3}$. 
The social planner’s preference for pricing structure under no net neutrality (NNN1, NNN2, NNN3)

- Proposition 5:
  Without net neutrality, the social planner always prefers the BSP charging a uniform fixed fee while downgrading heavy users.

  i.e., $SW_{NNN1} > SW_{NNN2} = SW_{NNN3}$. 
The social planner’s overall preference for pricing structure (all six options)

• Proposition 6:
  Overall, the social planner always prefers the BSP charging a uniform fixed fee while downgrading heavy users.

  \[ SW_{NNN1} > SW_{NN1} = SW_{NN2} = SW_{NN3} > SW_{NNN2} = SW_{NNN3}. \]
Differences between the BSP’s and the social planner’s preferences

• Proposition 7: The BSP’s choice deviates from the social optimum under three scenarios:

(Scenario 1) \( V_H - V_L \leq C_1 \)

(Scenario 2) \( C_2 < V_H - V_L \leq C_3 \)

(Scenario 3) \( V_H - V_L > C_4 \)

Revisit the figure of the BSP’s choice for user discrimination
Questions/Comments?