The Public Option: A non-regulatory alternative to Network Neutrality

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The Internet Landscape

- Internet Service Providers (ISPs)
  - Comcast
  - Time Warner Cable
  - SingTel

- Internet Content Providers (CPs)
  - Google
  - BitTorrent
  - Netflix

- Regulatory Authorities
  - Federal Communications Commission (FCC)
  - Infocomm Development Authority of Singapore (IDA)

- Users/Consumers
Network Neutrality

- Different notions: “freedom”, “innovation”...
  - a principle that advocates no restrictions by *ISPs* or governments on consumers' access to networks that participate in the Internet.
  - prevent restrictions on *content*, sites, platforms, types of attached equipment, and modes of communication. (Wikipedia)
Different Aspects of

- “Freedom of speech”
- Innovation of the Internet
- Survivability/profitability of the ISPs
- Our focus: Paid prioritization of content
Non-Neutral: Censorship

Not Happy!
Network Neutrality

Better! Happy?
Non-Neutral: Paid Prioritization
Next, as was done at the Mexican border, we'll militarize this gateway to make sure that only friendlies are admitted...

Total Information Control

Information Superhighway Toll Station
If you have to ask how much you can't afford it

Last free medium next 20 years
Public Option

Censored

Priority

Free Pass

Public Option
### Public Option in other contexts

- **Cross-Harbour Tunnel**: Opened 1972, Operator: Hong Kong Government, Cost: HK$ 10/20/10/15/30, Vehicles Daily '05: 121 700
Regulatory Preference

- Monopolistic scenarios:
  - Public Option $\succ$ Network Neutrality $\succ$ Hands Off the Internet

- Oligopolistic scenarios:
  - Hands Off the Internet $\succ$ Public Option $\succ$ Network Neutrality
Three-party model \((M, \mu, N)\)

- \(M\): population size (\# of end users).
- \(N\): set of content providers (CPs).
- \(\mu\): capacity of an ISP.
- \(\lambda_i\): throughput rate of CP \(i \in N\).
Unconstrained Demand

(Max) Throughput $\hat{\theta}_i (= 7)$

Population size $M (= 10)$

Content unconstrained throughput

$\hat{\lambda}_i = \alpha_i M \hat{\theta}_i (= 42)$

Content popularity

$\alpha_i (= 60\%)$
Demand Function $d_i(\theta_i)$

demanding # of users $\alpha_i M d_i(\theta_i)$
Demand Function $d_i(\theta_i)$

- Assumption 1: $d_i(\theta_i)$ is continuous and non-decreasing in $\theta_i$ with $d_i(\hat{\theta}_i) = 1$.

- More sensitive demand to throughput

- Throughput of CP $i$:
  \[ \lambda_i(\theta_i) = \alpha_i M d_i(\theta_i) \theta_i = \alpha_i M \rho_i(\theta_i) \]
Rate Allocation Mechanism

- Capacity $\mu$ & demands $d_i$s $\rightarrow$ throughput $\theta_i$s
- Axiom 1 (Throughput upper-bound)
  \[ \theta_i \leq \hat{\theta}_i \]
- Axiom 2 (Work-conserving)
  \[ \lambda_N = \sum_{i \in N} \lambda_i = \min \left( \mu, \sum_{i \in N} \hat{\lambda}_i \right) \]
- Axiom 3 (Monotonicity)
  \[ \theta_i(M, \mu_2, \mathcal{N}) \geq \theta_i(M, \mu_1, \mathcal{N}) \quad \forall \mu_2 \geq \mu_1 \]
Uniqueness of Rate Equilibrium

Theorem (Uniqueness): A system $(M, \mu, \mathcal{N})$ has a unique equilibrium \{\theta_i : i \in \mathcal{N}\} (and therefore \{\lambda_i : i \in \mathcal{N}\}) under Assumption 1 (about demand functions) and Axiom 1, 2 and 3 (about rate allocation mechanism).

User demand: $\theta_i \to d_i$
Rate allocation: $d_i \to \theta_i$ \implies Rate equilibrium: $(\theta_i^*, d_i^*)$
Rate Allocation Mechanism

- Axiom 4 (Independent of Scale)

\[ \theta_i(M, \mu, N) = \theta_i(\xi M, \xi \mu, N) \quad \forall \xi > 0 \]
Consumer Surplus: Definition

- Total and per user consumer surplus are

\[
CS = \sum_{i \in N} \phi_i \lambda_i (\theta_i); \quad \Phi = \frac{CS}{M} = \sum_{i \in N} \phi_i \alpha_i d_i(\theta_i) \theta_i.
\]

\(\phi_i\) : consumer surplus per unit traffic

Value to users \(\phi_i\)
Consumer Surplus: Monotonicity

- Theorem (Monotonicity): Under Axiom 4, the per user surplus is a non-decreasing function of the per user capacity \( \nu \equiv \frac{\mu}{M} \):

\[
\Phi(M, \mu, N) = \Phi(\nu, N)
\]
PMP-like Paid Prioritization

- $\kappa$ percentage of capacity dedicated to premium content providers
- $c$ per unit traffic charge for premium content

<table>
<thead>
<tr>
<th>Class</th>
<th>Capacity $\mu$</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium Class $\mathcal{P}$</td>
<td>$\kappa \mu$</td>
<td>$c$ /unit traffic</td>
</tr>
<tr>
<td>Ordinary Class $\mathcal{O}$</td>
<td>$(1 - \kappa) \mu$</td>
<td>$0$</td>
</tr>
</tbody>
</table>
PMP-like Paid Prioritization

ISP Payoff: \( c \sum_{i \in \mathcal{P}} \lambda_i = c \lambda_{\mathcal{P}} \)
Payoffs (Surplus)

- **Content Provider Payoff:**

\[
 u_i(\lambda_i) = \begin{cases} 
 v_i\lambda_i & \text{if } i \in \mathcal{O}, \\
 (v_i - c)\lambda_i & \text{if } i \in \mathcal{P}.
\end{cases}
\]

\(v_i\): content provider surplus per unit traffic

- **ISP Surplus** \(IS\): \(IS = c \sum_{i \in \mathcal{P}} \lambda_i = c \lambda_{\mathcal{P}}\);
  - Per user ISP surplus: \(\Psi = IS/M\)

- **Consumer Surplus**:

\(CS = \sum_{i \in \mathcal{N}} \phi_i \lambda_i\)
  - Per user consumer surplus: \(\Phi = CS/M\)
Type of Content

Profitability of CP $v_i$

Value to users $\phi_i$
Type of Content

- How about?

- How about?
Monopolistic Analysis

- A Two-stage Game Model \((M, \mu, N, I)\)
- Players: monopoly ISP \(I\) and the set of CPs \(N\)
- Strategies: ISP chooses \(s_I = (k, c)\). CPs choose service classes with \(s_N = (\O, \P)\).
- Rules: 1\(^{st}\) stage, ISP announces \(s_I\). 2\(^{nd}\) stage, CPs simultaneously reach a joint decision \(s_N\).
- Outcome: set \(\P\) of CPs shares capacity \(\kappa \mu\) and set \(\O\) of CPs share capacity \((1 - \kappa)\mu\).
Best response, Nash equilibrium

Lemma: Given \((\mathcal{O}, \mathcal{P})\), CP \(i\)'s best response to join the premium service class if
\[
(v_i - c)\rho_i(\kappa v, \mathcal{P} \cup \{i\}) \geq v_i \rho_i((1 - \kappa) v, \mathcal{O} \cup \{i\}).
\]

Nash equilibrium:
\[
\begin{cases}
  \frac{v_i - c}{v_i} \leq \frac{\rho_i((1 - \kappa) v, \mathcal{O})}{\rho_i(\kappa v, \mathcal{P} \cup \{i\})} & \text{if } i \in \mathcal{O}, \\
  \frac{\rho_i((1 - \kappa) v, \mathcal{O} \cup \{i\})}{\rho_i(\kappa v, \mathcal{P})} > \frac{\rho_i((1 - \kappa) v, \mathcal{O} \cup \{i\})}{\rho_i(\kappa v, \mathcal{P})} & \text{if } i \in \mathcal{P}.
\end{cases}
\]
Competitive equilibrium vs Nash

- Under the throughput-taking assumption:
  - Competitive equilibrium:
    \[ \frac{v_i - c}{v_i} \begin{cases} 
    \leq & \frac{\rho_i((1 - \kappa)v, O)}{\rho_i(kv, P)} & \text{if } i \in O, \\
    > & \frac{\rho_i((1 - \kappa)v, O)}{\rho_i(kv, P)} & \text{if } i \in P. 
    \end{cases} \]

- Advantages of competitive equilibrium:
  - Does not assume "common knowledge"
  - Like the price-taking assumption, valid for large number of players (CPs)
Monopolistic Analysis: Results

- **Theorem**: Given a fixed charge $c$, strategy $s_I = (\kappa, c)$ is dominated by $s'_I = (1, c)$.

  If the premium class is not saturated, i.e. $\lambda_p < \min \left\{ \mu, \sum_{v_i \geq c} \hat{\lambda}_i \right\}$,

  $s_I = (\kappa, c)$ is strictly dominated by $s'_I = (1, c)$.

- The monopoly ISP has incentive to allocate all capacity for the premium service class.
Surplus: Consumer $\Phi$ vs ISP $\Psi$
Regulatory Implications

- Ordinary service would be made a “damaged good”, which hurts consumer surplus.

- Implication: ISP should not be allowed to use non-work-conserving policies.

- Should we allow the ISP to charge an arbitrarily high price $c$? (not sure)
Type of Content

Profitability of CP $v_i$

Value to users $\phi_i$
High price $c$ is good when $\text{Profitability of CP } v_i$ is high and $\text{Value to users } \phi_i$ is also high.
High price $c$ is bad when

\[ \text{Profitability of CP } v_i \]

Value to users $\phi_i$
Oligopolistic Analysis

- A Two-stage Game Model \((M, \mu, \mathcal{N}, \mathcal{I})\)

  - 1\(^{\text{st}}\) stage: for each ISP \(I \in \mathcal{I}\)
    - It chooses \(s_I = (k, c)\) simultaneously.

  - 2\(^{\text{nd}}\) stage: at each ISP \(I \in \mathcal{I}\)
    - CPs choose service classes with \(s^I_N = (O_I, P_I)\)
    - Users move among ISPs until the per user surplus \(\Phi_I\) is the same, which determines the market share of the ISPs

- A different objective:
  - ISPs try to maximize their market share.
Duopolistic Analysis

ISP $I$ with $s_I = (k, c)$

ISP $J$ with $s_J = (0, 0)$
Surplus: Consumer $\Phi$ vs ISP $\Psi_I$
Market Share of ISP

- Priority service might be good for the non-neutral ISP when capacity is scarce.
- The non-neutral ISP obtains at most one half market share under abundant capacity.
Duopolistic Analysis: Results

- Theorem: In the duopolistic game, where an ISP $J$ is a Public Option ISP, i.e. $s_J = (0, 0)$, if $s_I$ maximizes the non-neutral ISP $I$’s market share in an equilibrium, then the consumer surplus $CS$ is also maximized under that equilibrium.

- Regulatory implication for monopoly cases:

Public Option $>$ Network Neutrality $>$ Hands Off the Internet
Theorem: Under any strategy profile \( s_{-I} \), if \( s_I \) is a best-response to \( s_{-I} \) that maximizes market share, then \( s_I \) is an \( \epsilon \)-best-response for the per capita consumer surplus \( \Phi \).

A Nash equilibrium for market share is also a \( \epsilon \)-Nash equilibrium for consumer surplus.

Oligopolistic scenarios:
Public Option? YES!

GET WELL
PUBLIC OPTION
NOW

Joe Raedle, Getty Images