Net Neutrality Debate: Impact of Competition among ISPs

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Abstract

- This paper provides a first game-theoretical analysis of relations between two competitive ISPs and a single CP, in the form of a four-level game.

- Authors show that while the complaint from ISPs is relevant with a such competitive model, inserting side payments does not solve the problem.
Introduction - Network Neutrality

"We should have some mechanism to charge CPs associated with other ISPs" (2005).

Former CEO Ed Whitacre

The New York Times

ISP vs. CPs

Net Neutrality Debate!
Motivation & Model

- Existing literatures related to net neutrality, in general, deals with a single ISP, and one or several CPs
  - Though, in practice, we often have ISPs in competition for customers, while for many services, the CPs are in a quasi monopole, a characteristic ISPs complain about (ex. YouTube)
Multi-level Game

1. Side payments decision
   ▫ In the neutral case: \( q_A \) and \( q_B \) are 0.
   ▫ In the non-neutral case: It can be determined either by
     • ISPs
     • CP
     • Regulator

2. ISP price decision
   ▫ ISPs determine \( p_A \) and \( p_B \) during a non-cooperative game

3. CP price decision
   ▫ The CP sets the price \( p_1 \)

4. User selection
   ▫ Users choose their ISP
Demand Function and Utilities

- **Demand Function**

\[ D := [D_0 - d\bar{p}]^+ \]

- where \( \bar{p} \) is the total price paid to access the network

- **Total Price**

\[
\begin{align*}
\bar{p}_A &= p_A + p_1 \\
\bar{p}_B &= p_B + p_1.
\end{align*}
\]

- **ISP Utilities**

\[
\begin{align*}
U_A &= D_A \cdot (p_A + q_A) \\
U_B &= D_B \cdot (p_B + q_B).
\end{align*}
\]

- **CP Utility**

\[ U_1 = D_A(p_1 - q_A) + D_B(p_1 - q_B). \]
User Equilibrium (level 4)

- In order to define the user eq’m the authors assume that users choose the cheapest way to access content
  - Wardrop’s principle: \( \bar{p}_A > \bar{p}_B \Rightarrow D_A = 0 \)
  \( \bar{p}_B > \bar{p}_A \Rightarrow D_B = 0 \).
- Total price (via an ISP with strictly positive demand)
  \( \bar{p} := \min(\bar{p}_A, \bar{p}_B) \)
- Total demand \( D = D_A + D_B \).
  - where
  \[
  D_A = D = D_0 - d\bar{p} \quad \text{if} \quad \bar{p}_B > \bar{p}_A \\
  D_B = D \quad \text{if} \quad \bar{p}_A > \bar{p}_B \\
  D_A = \alpha D = \alpha(D_0 - d\bar{p}) \quad \text{if} \quad \bar{p}_A = \bar{p}_B = \bar{p} \\
  D_B = (1 - \alpha)D = (1 - \alpha)(D_0 - d\bar{p})
  \]
  \( \alpha \in [0, 1] \)
  represents the portion of population going with A because of some non-monetary preferences

**Proposition 1.** For each \((p_A, p_B)\), there exists a unique user equilibrium defining \( D_A \) and \( D_B \).
CP Price Determination (level 3)

- After plugging the user eq’m determined in level 4, the CP problem is

  \[ \max_{p_1} U_1 \]

  \[
  U_1 = \begin{cases} 
  [D_0 - d(p_A + p_1)]^+ (p_1 - q_A) & \text{if } p_A < p_B \\
  [D_0 - d(p + p_1)]^+ & \text{if } p_A = p_B = p \\
  \times (p_1 - \alpha q_A - (1 - \alpha)q_B) & \text{if } p_A = p_B = p \\
  [D_0 - d(p_B + p_1)]^+ (p_1 - q_B) & \text{if } p_A > p_B,
  \end{cases}
  \]

- and the maximum of \( U_1 \) is therefore obtained at

  \[
  p_1^* = \begin{cases} 
  \frac{1}{2} \left( \frac{D_0}{d} + q_A - p_A \right) & \text{if } p_A < p_B \\
  \frac{1}{2} \left( \frac{D_0}{d} + \alpha (q_A - p) + (1 - \alpha)(q_B - p) \right) & \text{if } p_A = p_B = p \\
  \frac{1}{2} \left( \frac{D_0}{d} + q_B - p_B \right) & \text{if } p_A > p_B.
  \end{cases}
  \]

- Not surprisingly, the price \( p_1^* \) increases when
  - the demand sensitivity \( d \) decreases and
  - the side payments increase
Pricing Game between ISPs (level 2)

• Using the results determined in levels 3 and 4, we have

**Proposition 2.** Assuming an \( \epsilon \) close enough to zero, there is a unique equilibrium \((p'_A, p'_B)\) to the price war:

1) If \( q_A < q_B \), the equilibrium is \((-q_A, -q_A - \epsilon)\),
2) If \( q_A > q_B \), the equilibrium is \((-q_B - \epsilon, -q_B)\),
3) If \( q_A = q_B = q \), the equilibrium is \((-q, -q)\).

• It typically ends up with a Bertrand competition, in which ISPs decrease their price to attract all demand from the competitor, up to the moment where revenue becomes zero for one of them
  
  ▫ In this case, when the side payments \( q_A \) and \( q_B \) are positive, then it is the ISPs which give money to the end users, the money they are getting coming from the CP

\( \epsilon \) is a discretization value on the price range (ex. cents)
Pricing Game between ISPs (level 2)

- Best-response curves

\[ p_A < p_B \]

\[ p_A > p_B \]

Best-response curves in the price war when \( q_A < q_B \).

Best-response curves in the price war when \( q_A = q_B \).
Side Payments Determination (level 1)

1. Determined by the **CP** (unlikely in practice)

   \[
   U_1(q_A, q_B) = \begin{cases} 
   \frac{1}{4d}(D_0 - d(q_B - q_A - \epsilon))^2 & \text{if } q_A < q_B \\
   \frac{1}{4d}(D_0 - d(q_B - q_A - \epsilon))^2 & \text{if } q_A = q_B \\
   \frac{1}{4d}(D_0 - d(q_A - q_B - \epsilon))^2 & \text{if } q_A > q_B.
   \end{cases}
   \]

   - If the parameter \( \epsilon \) is very small, the optimum is obtained when \( q_A = q_B = q \)
   - Remark that the ISPs then make no profit at all, all benefits going to the CP with a total value \( \frac{D_0^2}{4d} \)

2. Determined by the **ISPs**, through a game

   \[
   U_A(q_A, q_B) = \begin{cases} 
   \frac{1}{2}[D_0 - (q_A - q_B - \epsilon)d] \times (q_A - q_B - \epsilon) & \text{if } q_A > q_B \\
   0 & \text{if } q_A = q_B = q \\
   0 & \text{if } q_A < q_B.
   \end{cases}
   \]

   \[
   U_B(q_A, q_B) = \begin{cases} 
   \frac{1}{2}[D_0 - (q_B - q_A - \epsilon)d] \times (q_B - q_A - \epsilon) & \text{if } q_B > q_A \\
   0 & \text{if } q_A = q_B = q \\
   0 & \text{if } q_B < q_A.
   \end{cases}
   \]

   - In this case, ISPs best interest is **always to play a larger side payment than his opponent**
   - As a consequence there is no NE, the payments naturally tends to \(+\infty\)
Side Payments Determination (level 1)

1. Determined by a **regulator**
   - A regulator can either decide to maximize the revenue of
     - the supply chain (sum of utilities of the ISPs plus the CP),
     - the user welfare (end-user surplus), or
     - the social welfare (including user welfare and all providers utilities)

1. **User welfare (UW)**
   \[
   \text{UW} = \int_{p=\bar{p}}^{+\infty} D(p)dp = \frac{d}{2} \left( \frac{D_0}{d} - \bar{p} \right)^2
   \]

2. **Total value of the supply chain**
   \[
   U_1 + U_A + U_B = \bar{p} \left[ D_0 - d\bar{p} \right]^+
   \]

3. **Social welfare (SW)**
   \[
   \text{SW} = U_1 + U_A + U_B + \text{UW} = \frac{1}{2d} \left( \frac{D_0^2}{d^2} - d^2\bar{p}^2 \right)
   \]
Side Payments Determination (level 1)

**Proposition 3.** When $\epsilon$ tends to zero, at the overall pricing equilibrium (including CP and ISPs decisions) the perceived price $\bar{p} = p_1^* + \min(p_A, p_B)$ tends to

$$\bar{p} = \frac{1}{2} \left( \frac{D_0}{d} + |q_A - q_B| \right).$$  \hspace{1cm} (12)

1. Side payments to maximize the supply chain value

$$U_1 + U_A + U_B = \begin{cases} 
\frac{D_0^2}{4d} - \frac{d}{4}(|q_A - q_B| - \epsilon)^2 & \text{if } q_A \neq q_B \\
\frac{D_0^2}{4d} & \text{if } q_A = q_B.
\end{cases}$$

- which is maximized when $q_A = q_B = q$ (and does not depend on $q$)

2. Side payments to maximize User Welfare (UW) or Social Welfare (SW)

- To maximize UW or SW, the side payments should be chosen so as to minimize the resulting perceived price $\bar{p}$.
- The perceived price is minimized when $q_A = q_B = q$
Side Payments Determination (level 1)

- On the efficiency of side payments
  - The previous results have highlighted the fact that equal side payments are likely to be selected
  - On the other hand, recall that when $q_A = q_B$ then no ISP makes any profit, and the CP takes all the supply chain surplus, that equals $\frac{D_0^2}{4d}$
  - This suggests that ISPs arguments regarding the CPs extracting most of the benefit is legitimate
  - However, the model suggests that side payments would not benefit to ISPs
Conclusion

• The idea of introducing side payments in the net neutrality debate was to ensure that ISPs would recover their cost and reinvest in the architecture but, as the authors have shown, this does not help the ISPs to get higher revenue.

• The reason for that is the Bertrand competition between ISPs which drives their revenue to zero.
  ▫ Side payments are “counter-balanced” by competition in the sense that side payments are poured back to end users in order to attract them.

• As a conclusion, side payments are actually not of interest for ISPs.
  ▫ They do not help in a competitive situation.

...which advocates net neutrality!!! However...
Criticism

1. The argument of ISPs to charge CPs comes from getting the portion of CPs’ profits obtained by advertising not from end-user revenue
   - Also, charging users by the CP has little effect on the user demand for Internet access
     - In reality, if a CP increases its price, it normally does not reduce the demand for Internet access (it just reduces the demand towards that CP (website))

<This paper’s model>

<recommended model 1>
Criticism

2. The concept of “non-neutrality” does not necessarily mean allowing ISPs to charge CPs. Rather, it is about ISPs charging CPs that are not directly associated to them.
Importance of the “model”

- I found a related work\(^1\) that uses the ‘recommended model 2’
  - The result is **totally opposite**

- Conclusion of P. Njoroge et al., 2010:
  - In the **non-neutral regime**, an ISP has a monopoly over the access to its consumer base
  - In the non-neutral regime, because it is easier to extract surplus through appropriate CP pricing, ISPs’ investment levels are larger
  - Because CPs’ quality is enhanced by ISPs’ quality, larger investment levels imply that CP’s profits increase
  - Similarly, consumer surplus increases as well

Social Welfare is larger in the non-neutral regime!!

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THANKS AND QUESTIONS