

# Network Neutrality

Bruno Tuffin

(based on joint works with P. L'Ecuyer, P. Maillé, G. Simon, N. Stier)

Séminaire ENS, 2017



# Outline

- 1 Context
- 2 What do we do on network neutrality?
  - Two illustrative models
- 3 More recent concern: isn't the current debate (definition) outdated?
- 4 Ex: CDNs and neutrality
- 5 Search neutrality
- 6 Conclusions

## Historical reminders

- Issue raised by Ed Whitacre, CEO of AT&T in 2005:
    - ▶ distant content providers use AT&T network without paying anything for it...
    - ▶ .. while transit prices keep decreasing...
    - ▶ ... and revenues from advertisement keep increasing for those content providers (and they do not pay “local” taxes).
  - Threat to differentiate service if not paying.
  - Raised protests worldwide from content providers and user associations.
    - ▶ Content and service providers are said to be afraid for service innovation
      - ★ only big content providers can afford to pay
    - ▶ User associations are afraid of the changes in the Internet philosophy.
- ⇒ **Network neutrality debate**
- Ex: ISP *Madison River Communications* (NC) fined in 2005 for preventing its clients from using VoIP in competition with its own “voice” offer.
  - Ex: Comcast in 2007 blocked P2P such as BitTorrent (illegality argument).




## A few historical elements in France

- YouTube blocked or slowed down by Free;
- **Opposite effect, zero rating**: SFR did launch a contract (RED) including unlimited YouTube videos, while others are counted in the authorized volume of data.
- YouTube *pays* Orange for its traffic
  - ▶ not so adept of neutrality ?
  - ▶ To generalize the principle and deter newcomers from entering?
- Skype, considered as a telecommunication operator (ARCEP vision in 2013; not anymore) or not? Blocking authorized? Complex problem.



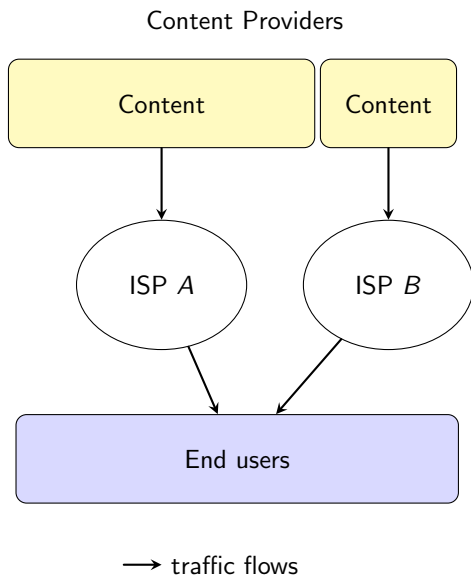
# Sensitive debate worldwide

- Even a political debate
- Economic against “universality/service” arguments
- Consultations worldwide in 2009-2010, with set of recommendations
- Is the debate closed? No, still active discussions
- **New public consultation** in 2016 by BEREC (European regulator) about guidelines on the implementation by regulators of new net neutrality rules
  - ▶ consultation closing on July 18
  - ▶ discussions of all French actors organized by ARCEP.

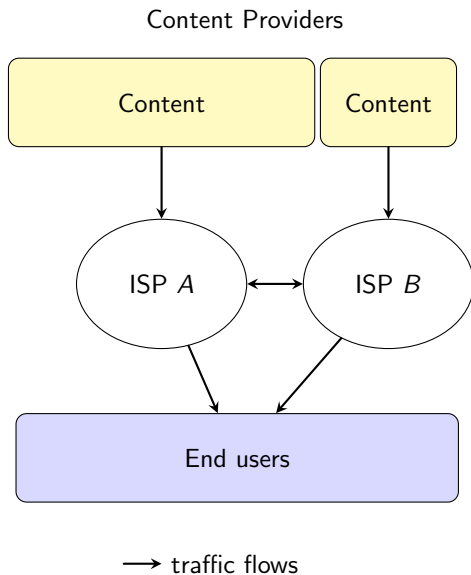


The screenshot shows the BEREC website header with the logo "Body of European Regulators for Electronic Communications BEREC". Navigation links include "Home", "BEREC", "BEREC Office", "Documents", "Net Neutrality", "Information Sharing Portal", "Public Consultations", and "Contacts". A search bar is present. Below the navigation, there are links for "Ongoing Public Consultations" and "Closed Public Consultations". The main content area features a heading: "Public consultation on draft BEREC Guidelines on implementation of net neutrality rules". Below this, the date "06 June 2016" is shown, along with a "Tweet" link. The text states: "The draft BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules was approved for public consultation at the BEREC Board of Regulators meeting in Vienna, Austria on 3 June 2016."

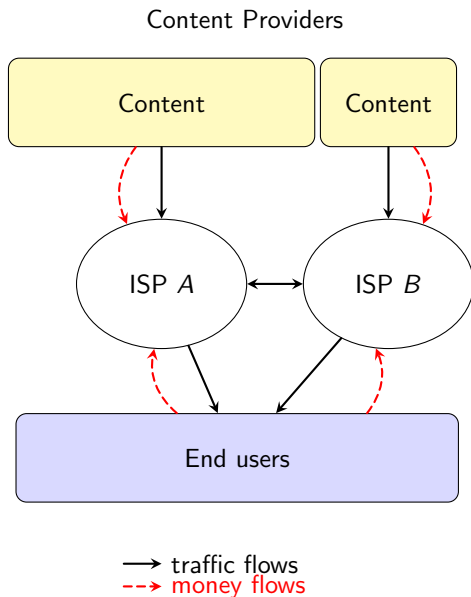
# Why the Network Neutrality debate?



# Why the Network Neutrality debate?

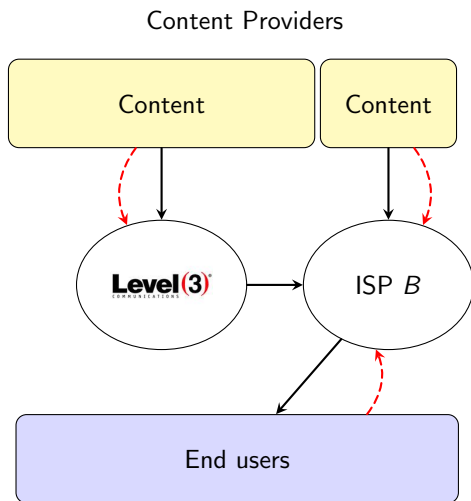


# Why the Network Neutrality debate?



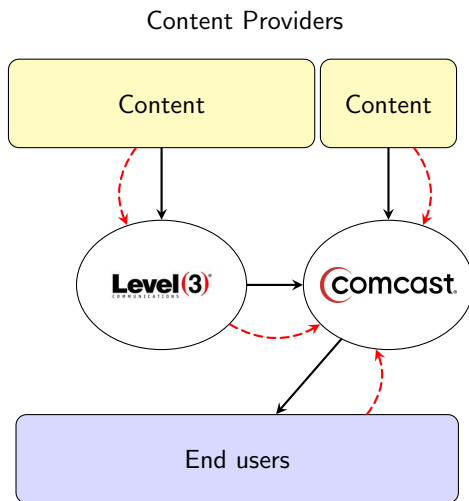


# Why the Network Neutrality debate?



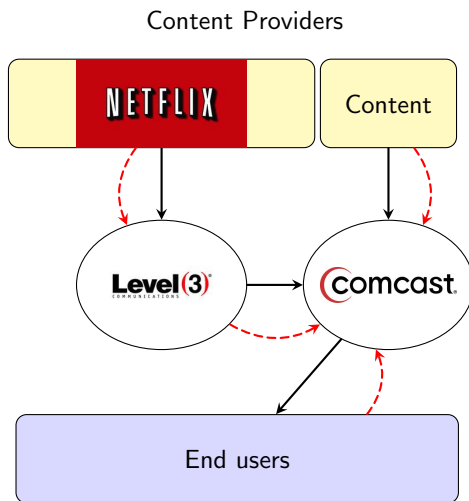
→ traffic flows  
--> money flows

# Why the Network Neutrality debate?



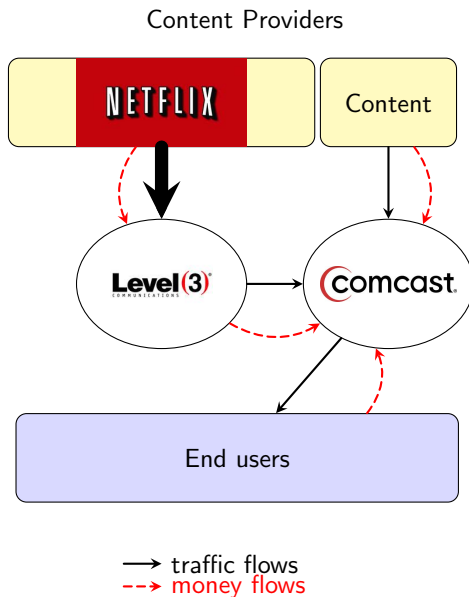
→ traffic flows  
--> money flows

# Why the Network Neutrality debate?

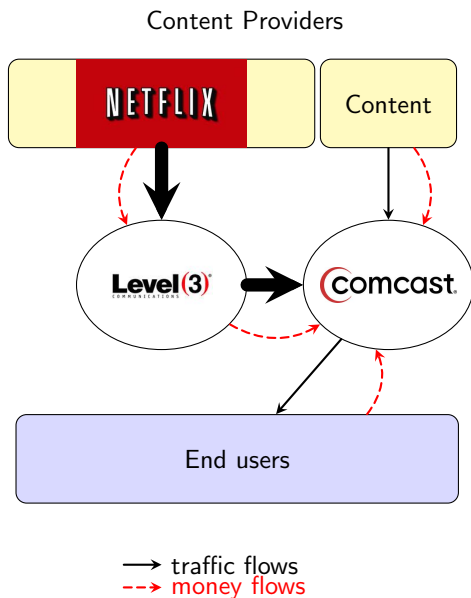


→ traffic flows  
--> money flows

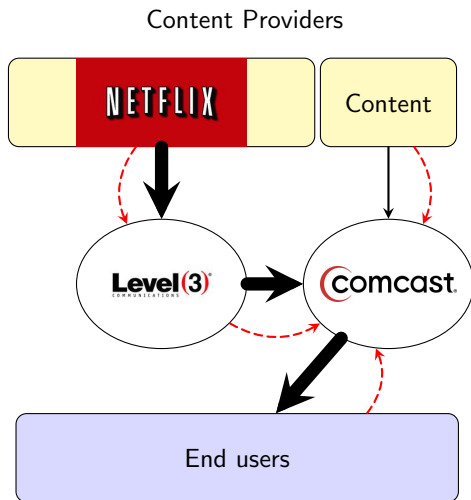
# Why the Network Neutrality debate?



# Why the Network Neutrality debate?

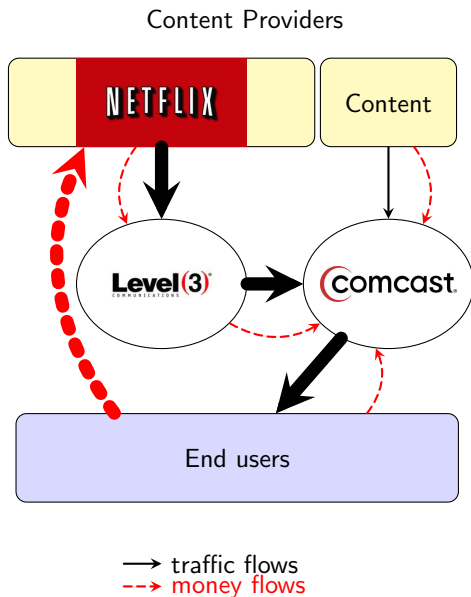


# Why the Network Neutrality debate?

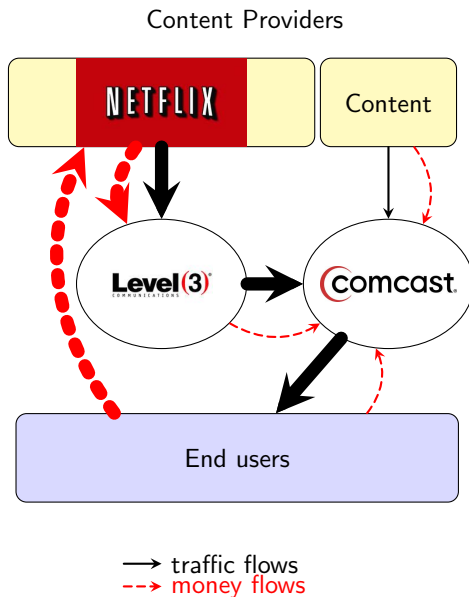


→ traffic flows  
--> money flows

# Why the Network Neutrality debate?



# Why the Network Neutrality debate?





## European parliament positioning (April 3rd, 2014)

### Definition (network neutrality)

The principle means that traffic should be treated equally, without discrimination, restriction or interference, independent of the sender, receiver, type, content, device, service or application.

The ISPs have to conform to this principle, but in “exceptional” cases:

- 1 a legal action;
- 2 to ensure the security and integrity of the network if confronted to attacks;
- 3 in case of *temporary* congestion of the network.

**Remark:** close to FCC (2005)

# The network as a public service or a commercial entity?

Maillé, Reichl & T., 2012

Two worlds with two different goals; a strict comparison difficult:

- an idealistic (neutral or weakly neutral) network as imagined initially by scientists, with an organization in layers, a low cost, and for which end-to-end connectivity and universality are the key issues
- a purely economic (non-neutral) view of the network

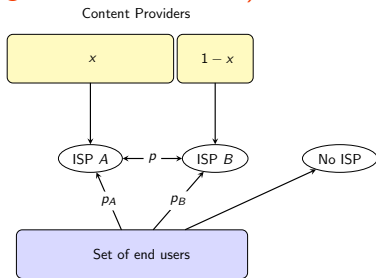
Commercial or non-commercial? That may be the real question.

# Outline

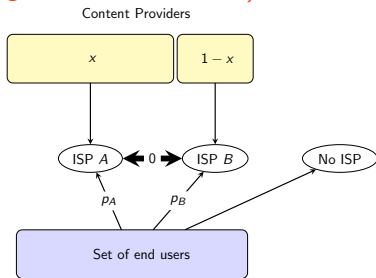
- 1 Context
- 2 What do we do on network neutrality?
  - Two illustrative models
- 3 More recent concern: isn't the current debate (definition) outdated?
- 4 Ex: CDNs and neutrality
- 5 Search neutrality
- 6 Conclusions



A related model of ISPs' interactions: what is the best scenario for each stakeholder (users, "big" ISP, "small" ISP)?

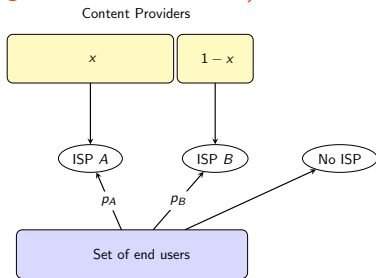


A related model of ISPs' interactions: what is the best scenario for each stakeholder (users, "big" ISP, "small" ISP)?



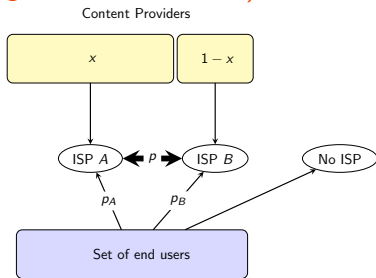
- **Peering**: all the content is shared for free ( $p = 0$ ).

A related model of ISPs' interactions: what is the best scenario for each stakeholder (users, "big" ISP, "small" ISP)?



- **Peering:**
- **No transfer:** clients of each ISP only access the contents owned by its ISP.

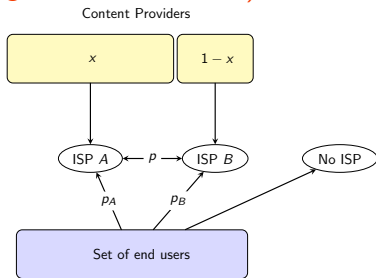
A related model of ISPs' interactions: what is the best scenario for each stakeholder (users, "big" ISP, "small" ISP)?



- Peering:
- No transfer:
- Paid transit: ISPs pay a price per volume of traffic coming from the other ISP. Transit price  $p$  by regulator, through negotiation...



## A related model of ISPs' interactions: what is the best scenario for each stakeholder (users, "big" ISP, "small" ISP)?



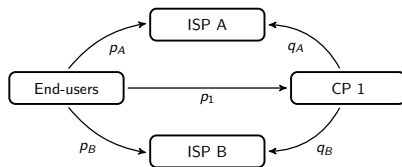
- **Peering**: all the content is shared for free ( $p = 0$ ).
- **No transfer**: clients of each ISP only access the contents owned by its ISP.
- **Paid transit**: ISPs pay a price per volume of traffic coming from the other ISP. Transit price  $p$  by regulator, through negotiation...

### Some results

- "No transfer" does not benefit to anybody.
- Compared to peering, **paid transit avoids price war** for end users when the price sensitivity of users is high.
- **The peering scenario maximizes user welfare.**

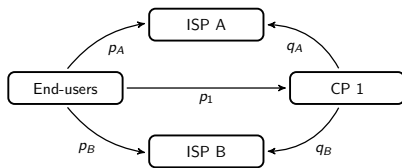
## Neutrality and competing ISPs

Investigate side payments effects, but with competitive ISPs.



## Neutrality and competing ISPs

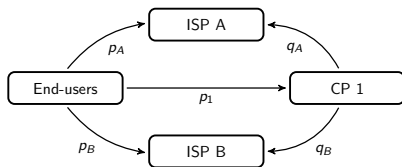
Investigate side payments effects, but with competitive ISPs.



- Decisions taken at different time scales
- ISPs competing on prices for users
  - ▶ Neutral case: side payments  $q_A$  and  $q_B$  fixed to 0, or determined as a common value.
  - ▶ Non-neutral case: determined either by the ISPs (in a game), the CP, or a regulator.

## Neutrality and competing ISPs

Investigate side payments effects, but with competitive ISPs.



- Decisions taken at different time scales
- ISPs competing on prices for users
  - ▶ Neutral case: side payments  $q_A$  and  $q_B$  fixed to 0, or determined as a common value.
  - ▶ Non-neutral case: determined either by the ISPs (in a game), the CP, or a regulator.

### Some results

- Side payments not always help ISPs
- Side payments may be beneficial to the CP!
- Side payments maximizing social, user welfare and CP revenue are the same
- Neutral case the most suitable to avoid disparities between ISPs revenues.
- If decided non-cooperatively, side payments benefit to only one ISP.

# Outline

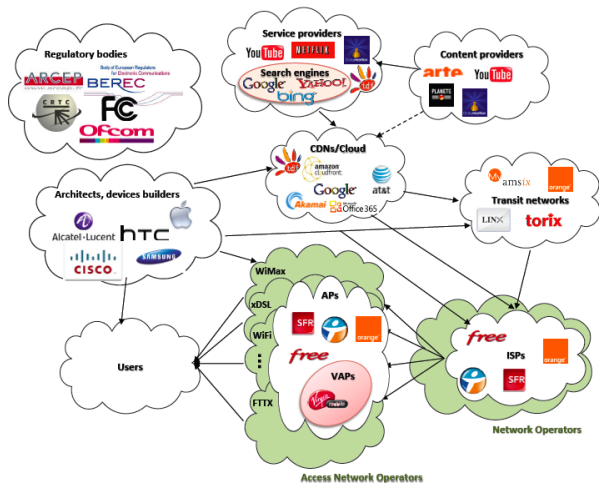
- 1 Context
- 2 What do we do on network neutrality?
  - Two illustrative models
- 3 More recent concern: isn't the current debate (definition) outdated?
- 4 Ex: CDNs and neutrality
- 5 Search neutrality
- 6 Conclusions

## But not everything is solved

- Model based on the supply chain **CP - ISP - users**: users want to access the CP and the ISP is the intermediary.

# But not everything is solved

- Model based on the supply chain **CP - ISP - users**: users want to access the CP and the ISP is the intermediary.
- The Internet ecosystem has become much more complex!



# Outline

- 1 Context
- 2 What do we do on network neutrality?
  - Two illustrative models
- 3 More recent concern: isn't the current debate (definition) outdated?
- 4 Ex: CDNs and neutrality
- 5 Search neutrality
- 6 Conclusions





- **CDN** = actor controlling a set of storage servers (Akamai: 170 000; over two billion dollars revenue in 2013)
- Content Providers (CPs) contract with them
- Goal: have content close to users
  - ▶ faster response time
  - ▶ reduced transit costs

**CDNs can discriminate by asking different charges without violating the packet-based neutrality rules!**

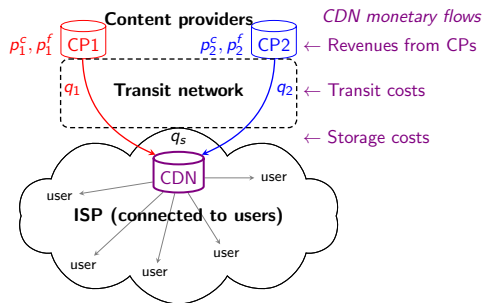
# Models illustrating this potential problem of a revenue-oriented CDN

# Models illustrating this potential problem of a revenue-oriented CDN

On competition between CPs

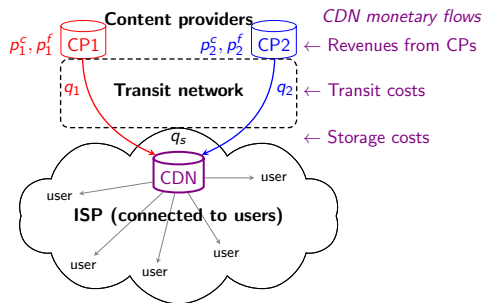
# Models illustrating this potential problem of a revenue-oriented CDN

## On competition between CPs



# Models illustrating this potential problem of a revenue-oriented CDN

## On competition between CPs

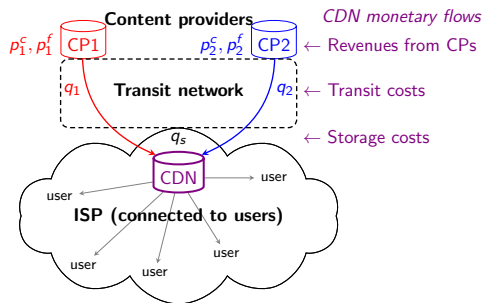


- Optimal pricing and caching strategies can be unfair.
- A big CP can harm a small one by paying more.

# Models illustrating this potential problem of a revenue-oriented CDN

## On competition between CPs

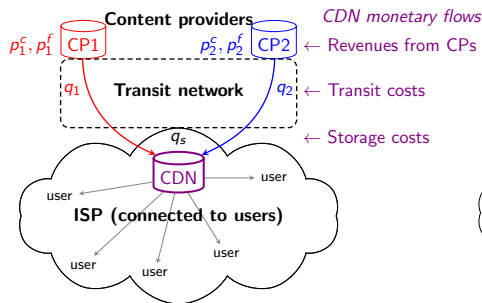
## On competition between ISPs



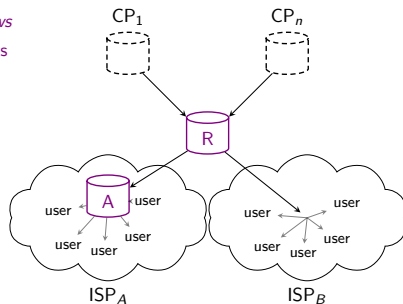
- Optimal pricing and caching strategies can be unfair.
- A big CP can harm a small one by paying more.

# Models illustrating this potential problem of a revenue-oriented CDN

## On competition between CPs



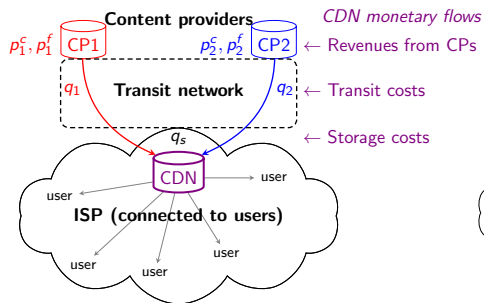
## On competition between ISPs



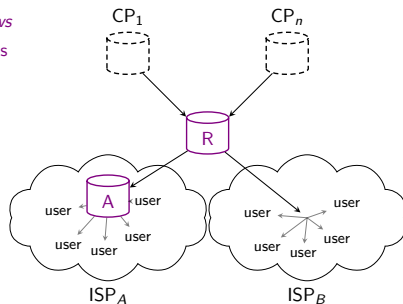
- Optimal pricing and caching strategies can be unfair.
- A big CP can harm a small one by paying more.

# Models illustrating this potential problem of a revenue-oriented CDN

## On competition between CPs



## On competition between ISPs



- Optimal pricing and caching strategies can be unfair.
- A big CP can harm a small one by paying more.

- Incentivizing to cache content in A can lead not to cache it in R.
- An ISP can harm the other by "welcoming" the CDN.



# Outline

- 1 Context
- 2 What do we do on network neutrality?
  - Two illustrative models
- 3 More recent concern: isn't the current debate (definition) outdated?
- 4 Ex: CDNs and neutrality
- 5 Search neutrality
- 6 Conclusions

## Ex: search engines

- Major role in the Internet economy:
  - ▶ most used way to access content
  - ▶ approximately 20 billions of requests per month treated in the USA through computers only
- Search engines provide an ordered list of links –the *organic results*– from a set of keywords

organic results are supposed to be based on **relevance**

as opposed to *sponsored* links

Search engines are suspected to bias their organic ordering (in function of what would bring more revenue) without saying it transparently.

- Favoring their own content (ex: YouTube for Google)

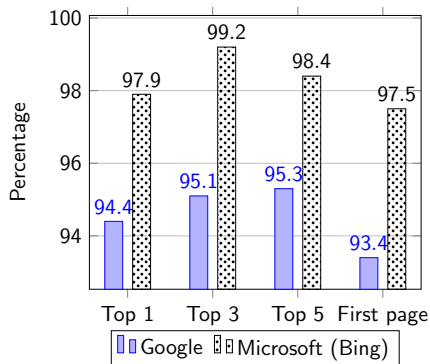


# Do search engines return biased results?

Do search engines return biased results?

**YES!**

## Do search engines return biased results?



Percentage of Google or Bing search results with **own content not ranked similarly** by any rival search engine (Wright, 2012).

- Microsoft content is 26 times more likely to be displayed on the first page of Bing than on any other search engine
- Google content appears 17 times more often on the first page of a Google search than on the other search engines

## Trade-off between relevance (long term profit) and revenue (short term)

More relevance brings more customers in the long term because it builds reputation.

Model: a search = a random vector  $(R_1, G_1, R_2, G_2, \dots)$

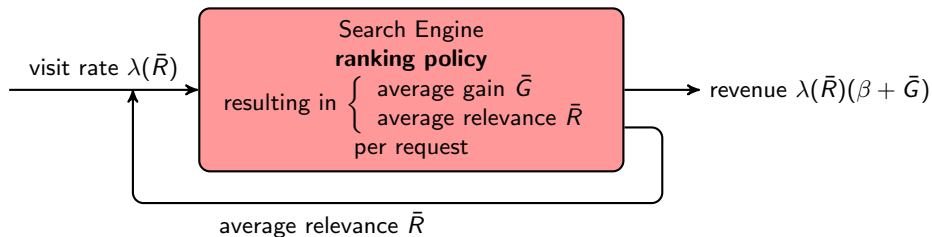
$R_i$ : relevance of page  $i$

$G_i$ : gain of page  $i$  for search engine

$\beta$ : avg sponsored search revenue per visit

## Trade-off between relevance (long term profit) and revenue (short term)

More relevance brings more customers in the long term because it builds reputation.



Model: a search = a random vector  $(R_1, G_1, R_2, G_2, \dots)$

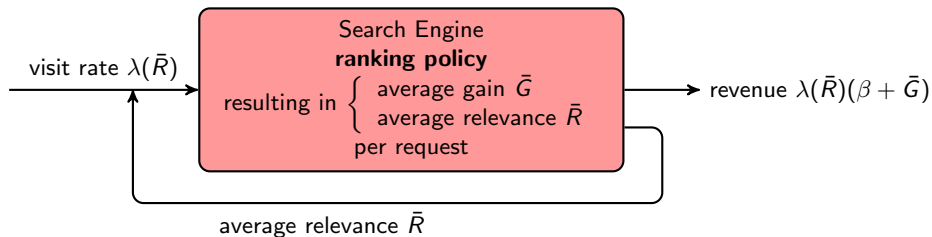
$R_i$ : relevance of page  $i$

$G_i$ : gain of page  $i$  for search engine

$\beta$ : avg sponsored search revenue per visit

## Trade-off between relevance (long term profit) and revenue (short term)

More relevance brings more customers in the long term because it builds reputation.

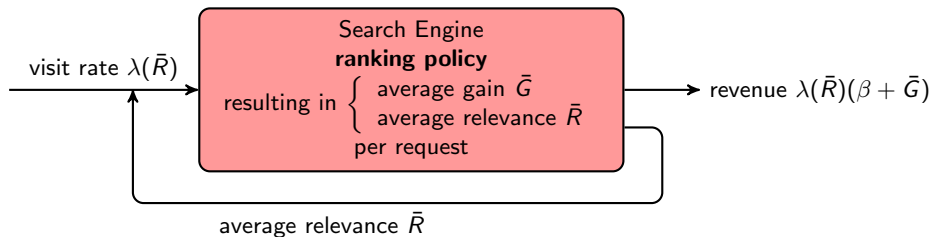


- characterization of optimal ranking policies
- for a continuous distribution of requests:
  - rank according to  $R_i + \rho G_i$  for some  $\rho > 0$



## Trade-off between relevance (long term profit) and revenue (short term)

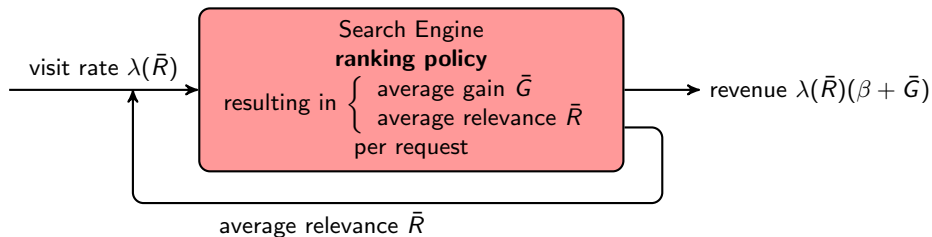
More relevance brings more customers in the long term because it builds reputation.



- characterization of optimal ranking policies
- for a continuous distribution of requests:
  - rank according to  $R_i + \rho G_i$  for some  $\rho > 0$
  - algorithm to find opt. ranking:  $\rho$  as a fixed-point computed numerically

## Trade-off between relevance (long term profit) and revenue (short term)

More relevance brings more customers in the long term because it builds reputation.



- characterization of optimal ranking policies
- for a continuous distribution of requests:
  - rank according to  $R_i + \rho G_i$  for some  $\rho > 0$
  - algorithm to find opt. ranking:  $\rho$  as a fixed-point computed numerically

Analyze the consequences on all actors

# Impact of a non-neutral ranking with a vertically integrated CP with the SE

Comparing avg advertisement revenue from a search to the avg revenue from a visit to the integrated CP.

(With artificial data not presented here; reproducible experiment)

Policy (% rev. adv./CP rev.)	Relevance	Integ. CP revenue	other CP revenue	Integ. CP visit rate	other CP visit rate
Neutral	0.635	0.028	0.0283	0.057	0.057
Non-neutral (200%)	(-3%)	(+136%)	(-14%)	(+96%)	(-14%)
Non-neutral (100%)	(-7%)	(+200%)	(-24%)	(+146%)	(-25%)
Non-neutral (50%)	(-11%)	(+232%)	(-32%)	(+177%)	(-32%)

# Outline

- 1 Context
- 2 What do we do on network neutrality?
  - Two illustrative models
- 3 More recent concern: isn't the current debate (definition) outdated?
- 4 Ex: CDNs and neutrality
- 5 Search neutrality
- 6 Conclusions

# Conclusions

- Network neutrality: an old problem, still not solved, and very sensitive
- A focus on ISPs, but actually a much more complex problem with a constantly **evolving ecosystem**
- ARCEP has defined a text with (voluntarily) **grey zones** (ex: what is “traffic”?)
- Modeling and analysis through game theory helpful to better understand actors' strategies and consequences
  - ▶ What about **vertical integration** (controlling several steps of the supply chain)? A way to circumvent some defined rules and differentiate service elsewhere?
  - ▶ Another example: **YouTube giving a grade to ISPs** for the quality of YouTube videos; an incentive to differentiate quality in favor of YouTube in order to attract customers?

## A last hot “grey” zone: zero rating/sponsored mobile data

- Zero rating: not counting an application in data caps
  - ▶ Ex: SFR with YouTube few years ago
- Sponsored data: a service/content provider can *pay* for to remove its data from data caps
  - ▶ Ex: Facebook in developing markets
  - ▶ AT&T offers sponsored data in Jan. 2014.
- Is it against the net neutrality principle?
- Is it bad for customers?
- Does it hurt competition?
- Zero rating forbidden; but questions about sponsored data
  - ▶ The Net Neutrality rules do not explicitly prohibit sponsored data or data cap
  - ▶ When vertical integration: hidden zero rating.

## Few references on models described during this presentation

- P. Maille and B. Tuffin. *Telecommunication Network Economics: From Theory to Applications*. Cambridge University Press, 2014
- P. Maille, P. Reichl and B. Tuffin. Internet Governance and Economics of Network Neutrality. In *Telecommunications Economics - Selected Results of the COST Action IS605 Econtel*, A. Antoniadis and B. Stiller (Eds.), Lecture Notes in Computer Science, Springer-Verlag, pages 108-116, 2012.
- P. Coucheney, P. Maille and B. Tuffin. Impact of Reputation-Sensitive Users and Competition Between ISPs on the Net Neutrality Debate. *IEEE Transactions on Network and Service Management*, Vol. 10, Num. 4, Dec. 2014.
- P. Coucheney, P. Maille and B. Tuffin. Network Neutrality Debate and ISP Inter-Relations: Traffic Exchange, Revenue Sharing, and Disconnection Threat. *NETNOMICS: Economic Research and Electronic Networking*. Volume 15, Issue 3, pp 155-182, November 2014.
- E. Gourdin, P. Maille, G. Simon and B. Tuffin. The Economics of CDNs and Their Impact on Service Fairness. *IEEE Transactions on Network and Service Management*. To appear.
- P. L'Ecuyer, P. Maille, N. Stier-Moses, and B. Tuffin. Revenue-Maximizing Rankings for Online Platforms with Quality-Sensitive Consumers. *Operations*. To appear.