Economics of Technological Games Among Telecommunication Service Providers

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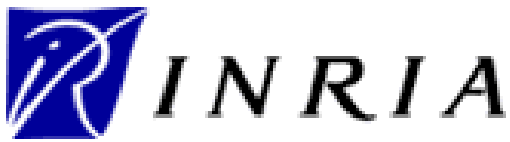

Context

- The Internet has evolved from an academic to a commercial network with providers in competition for customers and services.
- Most works on pricing are dealing with a monopoly, but
  - competition forces providers to decide about prices and others depending on competitors' ones.
  - some a priori promising pricing schemes may not resist to competition.
- Sometimes Providers even operate on different technologies (Fixed, WiFi, 3G, WiMAX...), or on several simultaneously.
- Also, impact of competition on capacity investment? Do they have interest in investing (especially when congestion pricing is used)?

Outline

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- Development of new technologies in a competitive context
- Should a provider invest in infrastructure or/and licence?
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- Three-level games for three time scales:
  - Highest level: operators decide on which technologies to invest (they may already own infrastructure/license)
  - Intermediate level: war on prices between operators
  - Lowest level: users choose their provider depending on the best combination of price and available quality of service.

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Game analysis: backward induction

- Lowest level game: Wardrop equilibrium for users
  - for fixed implemented techonologies and prices
  - Users (infinitesimal) have terminals with multiple interfaces and choose the "best" couple (provider, technology) depending on QoS and prices
  - There always exists a user equilibrium.

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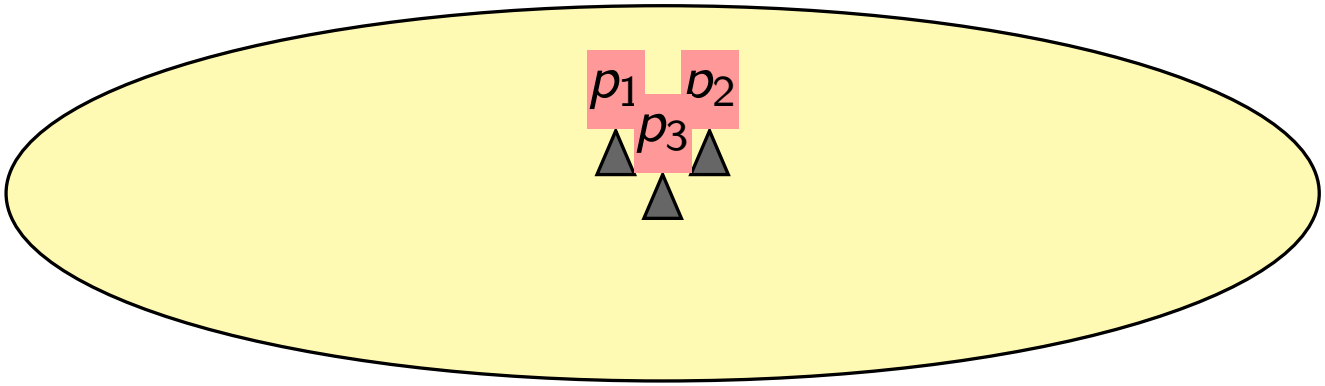

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$$\text{Perceived price } \bar{p} = \underbrace{p_i}_{\text{price for prov. } i} + \underbrace{\ell_t(d_t)}_{\text{congestion cost}}$$

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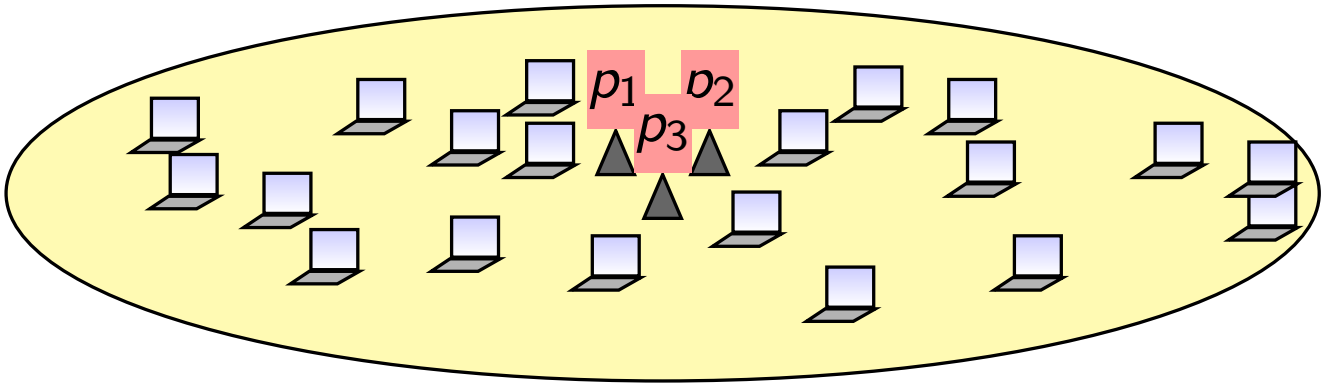

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- Highest level: Technological game
  - Providers choose their subset $\mathcal{T}_i$ of implemented technologies, resulting in a (multidimensional) matrix of revenues $(R_1(\mathcal{T}_1, \mathcal{T}_2), R_2(\mathcal{T}_1, \mathcal{T}_2))_{\mathcal{T}}$
  - and a cost matrix $C = (c_1(\mathcal{T}_1), c_2(\mathcal{T}_2))_{\mathcal{T}_1, \mathcal{T}_2 \subset \mathcal{T}}$.
  - Goal of each provider i: maximize net benefit

$$B_i(\mathcal{T}) = R_i(\mathcal{T}) - \sum_{t \in \mathcal{T}_i} c_{i,t} = \sum_{t \in \mathcal{T}_i} (p_i^* d_{i,t}^* - c_{i,t}).$$

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A case study as an illustration: a WiFi-positionned provider against a 3G one

- a WiFi-installed provider (1), Free, wishing to extend her position against a 3G-installed provider (2), Orange.
- Cost of the fourth licence in France (Free is buying): 240 M€.

1 \2	∅	3G	WiM.	3G,WiM.	WiFi	WiFi,3G	WiFi,WiM.	WiFi,3G,WiM.
∅	0;0	0;1929	0;2555	0;3716	0;2178	0;3629	0;4047	0;**4778**
3G	1437;0	1167;1679	1057;2198	810;3141	1208;1935	937;3161	826;3493	590;**4000**
WiMAX	2555;0	2198;1549	2040;2040	1665;2875	2237;1837	1865;2954	1708;3238	**1368**;**3628**
3G,WiMAX	3224;0	2649;1302	2383;1665	1781;2273	**2715**;1616	**2100**;2488	**1834**;2664	1235;**2817**
WiFi	2228;0	1985;1700	1887;2237	1666;**3207**	0;-50	-	-	-
WiFi,3G	3187;0	2719;1429	2512;1865	2046;**2592**	-	-	-	-
WiFi,WiM.	4097;0	3543;1318	**3288**;1708	**2714**;**2326**	-	-	-	-
WiFi,3G,WiM.	**4336**;0	**3558**;1082	3186;1368	2375;**1727**	-	-	-	-

- Two non symetric Nash equilibria. No investment on 3G for Free
- By reducing a bit more the licence cost, 3G investment for Free: threshold easy to compute.

Computing the Price of Anarchy (distance to the optimal point)

1 \2	∅	3G	WiM.	3G,WiM.	WiFi	WiFi,3G	WiFi,WiM.	WiFi,3G,WiM.
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Provider revenues; $\text{PoA} = \frac{2714+2326}{1368+3628} = 1.0088$

1 \2	∅	3G	WiM.	3G,WiM.	WiFi	WiFi,3G	WiFi,WiM.	WiFi,3G,WiM.
∅	0.0	74	182	662	54	384	600	1396
3G	74	486	726	1442	408	938	1262	2282
WiMAX	182	726	975	1785	662	1368	1755	**2709**
3G.WiMAX	662	1442	1785	2799	1368	2305	2799	4087
WiFi	54	408	662	1368	103	-	-	-
WiFi,3G	384	938	1368	2305	-	-	-	-
WiFi,WiM.	600	1262	1755	2799	-	-	-	-
WiFi,3G,WiM.	1395	2282	**2709**	4087	-	-	-	-

User welfare; $\text{PoA} = \frac{4087}{2709} = 1.51$

Second case study as an illustration: A 3G technology-positioned provider against a 3G-WiFi one

(in France, Bouygues vs SFR)

1 \2	∅	3G	WiM.	3G,WiM.	WiFi	WiFi,3G	WiFi,WiM.	WiFi,3G,WiM.
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3G	1929;0	1659;1679	1549;2198	1302;3141	1700;1935	1429;3161	1318 ;3493	1082;**4000**
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WiFi,3G,WiM.	**4828**;0	**4050**;1082	**3678**;1368	**2867**;**1727**	-	-	-	-

- Assumptions:
  - WiFi infrastructure cost is assumed to be equal to 50 € per month
  - 3G licence costs 649 M€ and is paid over 10 years

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- Assumptions:
  - WiFi infrastructure cost is assumed to be equal to 50 € per month
  - 3G licence costs 649 M€ and is paid over 10 years
- There exist two symmetric Nash equilibria on technologies. Both providers have an interest to invest in the WiMAX technology and to keep their 3G infrastructure active.
- User and social welfare are maximized at equilibrium, thus here regulation on the 3G licence price would bring no improvement.

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Conclusions and perspectives

- Contributions
  - Competition model on prices and technologies between operators and on demand between users
  - Numerical study of the equilibria and the regulation impact

- Ongoing extensions
  - Finer demand modeling for shared-spectrum technologies (e.g., WiFi) to avoid the "total" price war
- Other possible improvements:
  - A more accurate expression of the total demand function (would need more data from operators)
  - Game on capacities between operators