Η Χρέωση ως Μηχανισμός Ελέγχου Δικτύων

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Why Charge for Telecommunication Services ?

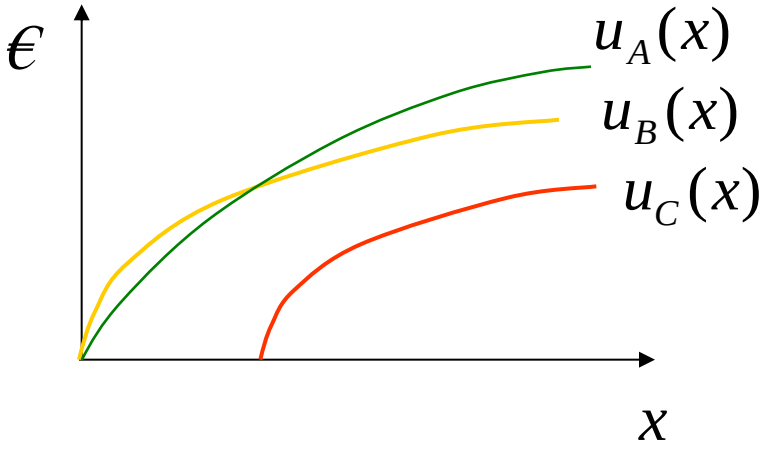
- In order for the Network (or Service) Provider to:
  - Recover costs
  - Make profits and save capital for future expansion
  - Control the system:
    - examples: charging of applications for admission to U.S. university
    - charging for street-parking in a city
  - Obtain information from users
    - examples: special call packages for long-distance fixed telephony or for mobile telephony
      → their adoption is indicative of user's type and *future* behavior

Terminology

- price: correlated with service unit
  - E.g. €/Mbyte of €/callminute
- tariff: charge structure
  - more general form of charging (i.e., *a+px*)
  - *control mechanism*
- charge: total amount that must be paid

Utility function

- Each consumer is characterized by a utility function $u(x)$
  - Translates into monetary units the benefit/satisfaction of the consumer from the use of the particular network resource or service
    - Expresses consumer's willingness-to-pay
    - Can also have the meaning of benefit from trading, reselling



$$u_A(10) = 5, u_B(10) = 2$$

Charging Components

1. Fixed charge
   → e.g.: monthly flat rate charging of Internet access

2. Usage charge
   → e.g.: fixed telephony is charged on time and distance
   - may be hard to quantify the "unit" of usage
   - E.g. bursty traffic should not be charged on volume only, because it is harder to multiplex than a constant-rate traffic stream (generating the same volume), and thus "consumes" more resources.

Charging Components

3. Congestion charge
   → its level depends on the congestion encountered or caused, similarly to highway tolls
4. Quality charge → often combined with usage or flat charges

- A charge of a telecommunication service constitutes a combination of the above components

Examples: a) monthly flat charge of Internet access depends on access rate, i.e. on a "quality" factor.

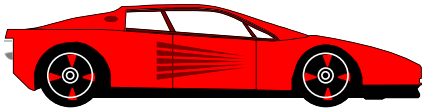
b) Often, the following combination applies:

Usage + Congestion + Quality → Variable charge

Congestion Charge

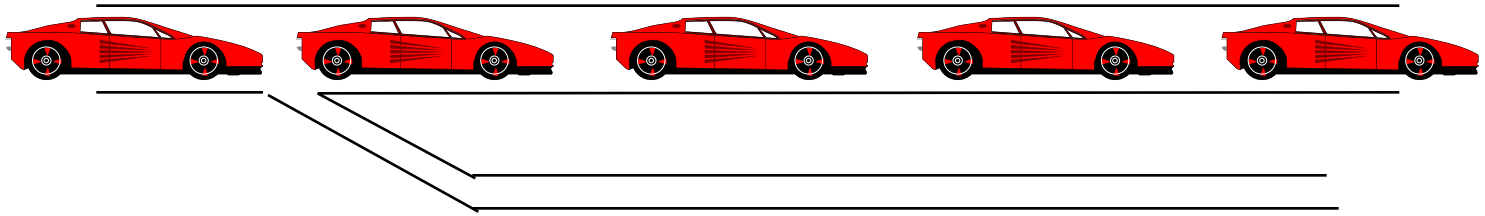
- Depends on congestion *during* service
- Applies to cases where:
  - everyone can be served, but
  - congestion results in service quality degradation

    E.g. highways, Internet
- Example: Charging access to highways, according to the a priori set congestion charge

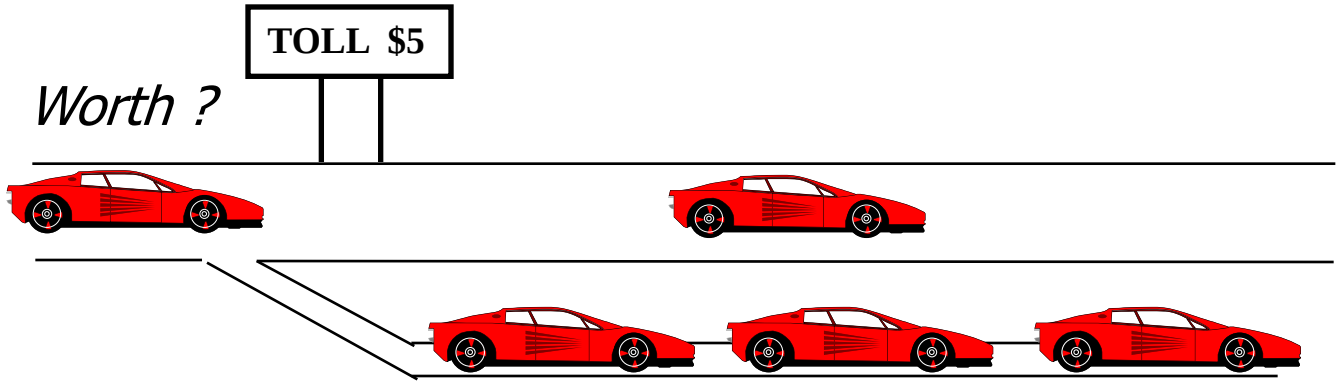


Congestion Charge (continued)

- Free access → traffic in highway is heavy



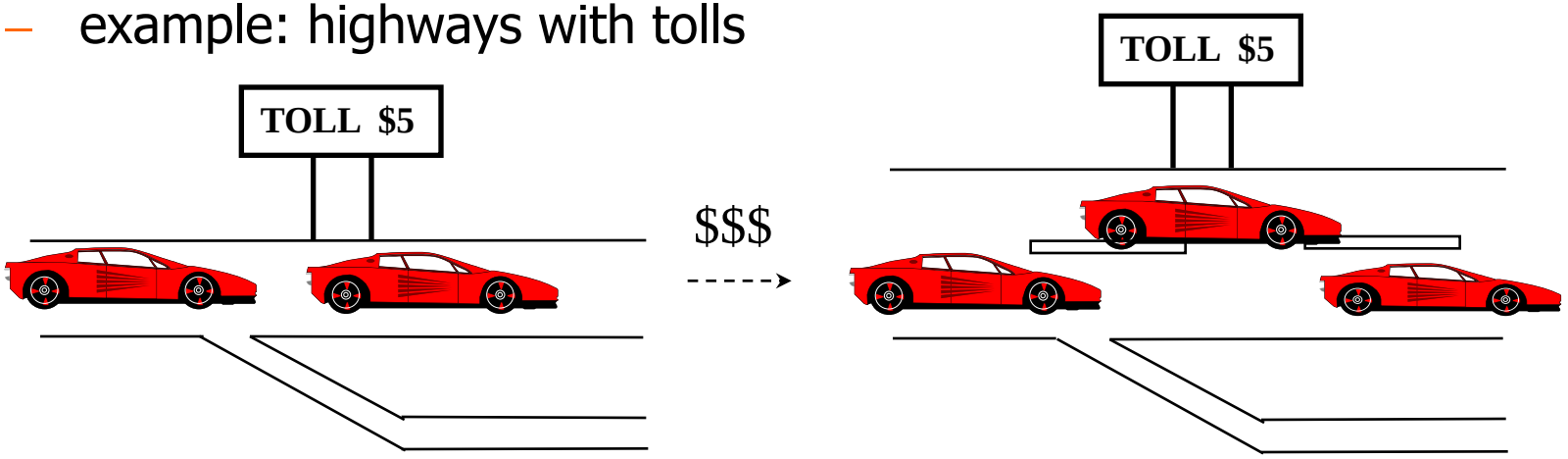
- Paid Access → traffic in highway is lighter



Capacity Expansion

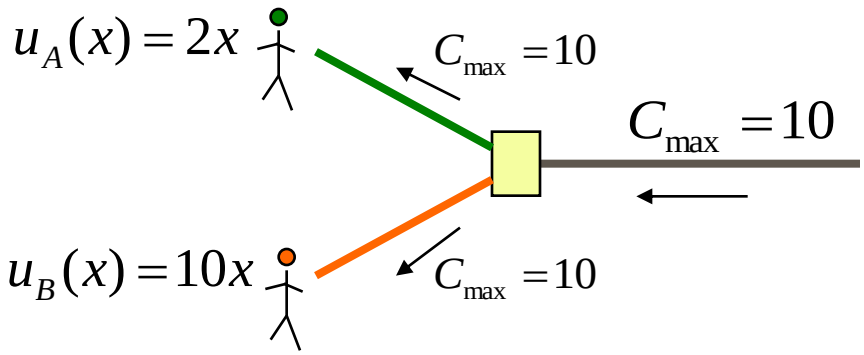
- A network provider should expand capacity upon congestion
  - social welfare can be further increased, *despite* the cost for additional capacity

- Economic theory suggests that expansion can be funded by re-investing the revenue from congestion charges
  - example: highways with tolls



Fixed and Variable charges

- Fixed charge: related to connection cost
- Variable charge: related with the size of consumption
  - Recovery of usage cost,
  - Control mechanism (of priority) of consumer



Cost = 1€ /unit

Connection Cost = 5€

Cost based charging: $5 + x$

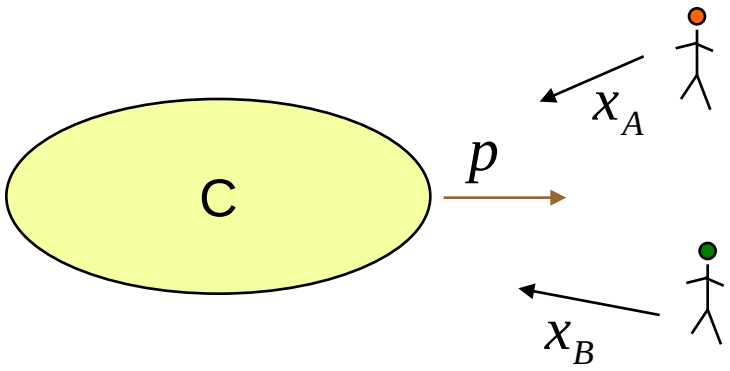
Every user receives $x = C_{\max} / 2 = 5$

Is it economically optimal ?

Pricing as a control mechanism (I)

- Service provider does not know the utility function of the consumers
- Consumers are pursuing their own benefit
- The quantity of the available service is finite
- How can the total benefit of the consumers be maximized? The network profit?
- **Pricing Mechanism!**

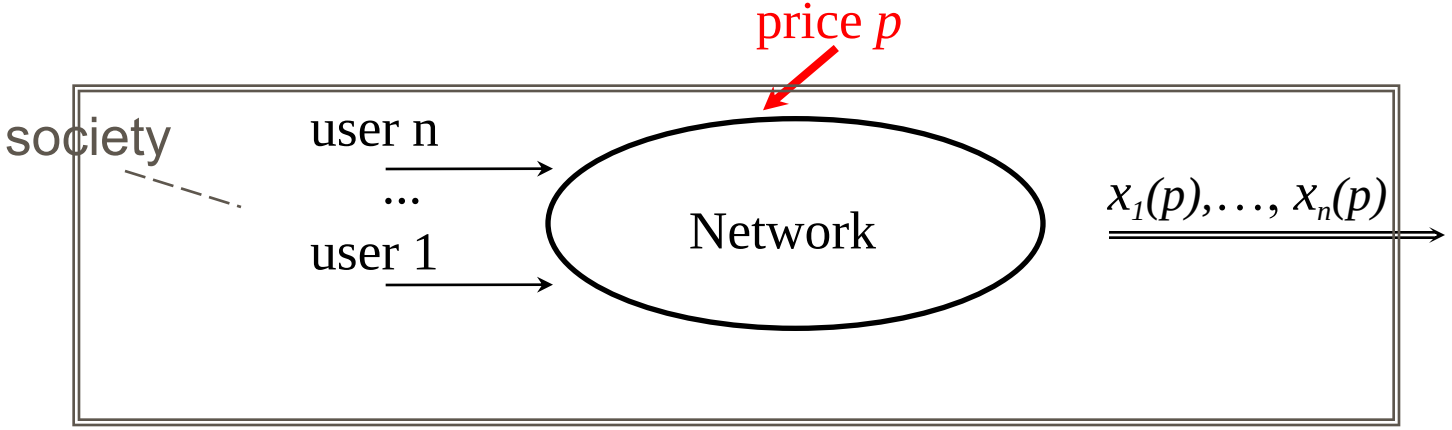
How much should I ask if the price is *p* ?



How is the problem specialized for networks ?

Charging as Control Mechanism

- Charges can be used as an internal control mechanism of the system provider & users to reach the social optimum
- Example: Socially Optimal Bandwidth Allocation
  - Network Provider sells bandwidth at a price p per kbps,
  - Given this price, each user i selects amount $x_i(p)$ of kbps purchased
  - Provider pays for capacity with the revenue collected
  - There exists an equilibium price p that leads to social optimum, i.e. maximizes the sum of user utilities (= social welfare)



More formally (I)

- One link, with capacity C shared by users with concave utility functions
- Social welfare maximization problem:

$$\max_{\{x_i\}} \sum_i u_i(x_i) \quad s.t. \quad \sum_i x_i \le C \quad (1)$$

- Mathematical solution (requires global information)
  → Maximize the Lagrangian

$$\max_{\{\lambda, x_i\}} L(\lambda, \{x_i\}) = \sum_i u_i(x_i) - \lambda(\sum_i x_i - C)$$

The optimal point of (1) is characterized by $\lambda, \{x_i\}$ for which:

$$\sum_i x_i = C, \ \frac{\partial u_i}{\partial x_i} = \lambda$$

More formally (II)

- Distributed solution of the problem with economic mechanism → use price $p = \lambda$
- The user solves his own net benefit maximization:

  $\max[u_i(x_i) - px_i]$ the condition for which is: $\frac{\partial u_i}{\partial x_i} = p$
- Price p discovered iteratively by means of *tattonement* process → provider updates market price p in order to "lead" total demand to become equal to the capacity C.
- Under general market conditions the market price p converges to the price λ of the centralized problem (i.e. the Lagrange multiplier)
  - Approach extended by Kelly et al. to networks

Incentives

- A charging scheme influences users' demand, according to the incentives it offers to the user for individual optimization
- Each individual user's behavior influences the social well-being (welfare)
- A charging scheme is incentive compatible if individual user optimization also results in social optimization
  - Applies to mechanism of slide 14

Examples of Incentives

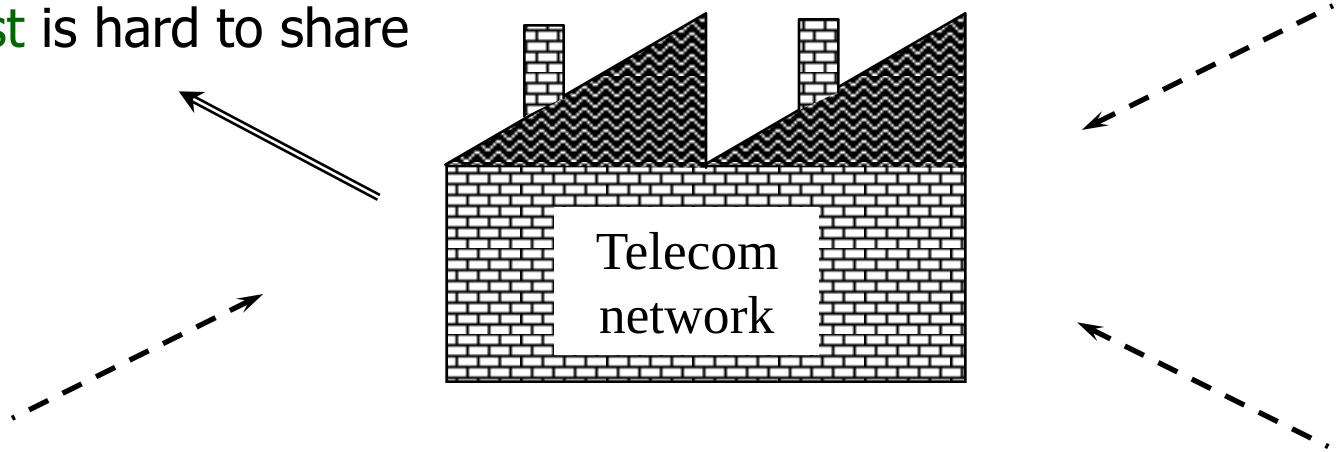
- Wrong Incentives
  - Monthly flat charge for Internet access
    → DSL connections left permanently open, thus giving rise to the need for more ports in the DSLAMs
  - Free night use of mobile telephones (U.K. – late 1990s)
    → *blocking:* telephones were left open for long hours

Examples of Incentives

- Right Incentives
  - Combination of Usage- and congestion-based charging of Internet
    → considered as an effective way to avoid congestion
  - Time-of-day charging in telephony and power
    → shifting of non-business calls off the peak period
    → satisfaction of both business and non-business users

Story on Charging Internet and Broadband Services

"produces" services
from shared resources
- usage is hard to quantify
- cost is hard to share



network theorists
- write articles

network engineers
- technical standards
- may leave concrete charging solutions for later

economists
- complex economic models
- overlook many critical details of technology