HY537: Έλεγχος Πόρων και Επίδοση σε Ευρυζωνικά Δίκτυα

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Pricing and network control
Incentives
Simple modeling

Network externalities

- *Network externalities*: action by one user affects all other users
- *Positive externalities*: value of a network increases as square of users (Metcalf's law)
- *Negative externalities*: when a user accesses a shared resource it increases congestion which affects all users
- *Positive externality* in peer-to-peer networks: all peers benefit when one peer shares its resources

Pricing

- Prices affect demand: e.g. lowering prices increases demand
- Prices can be used to control congestion
- Competition can drive prices to marginal cost
  - Large fixed cost of constructing a network
  - If there is no congestion, marginal cost of providing one additional unit of service is almost zero
- Networks and information goods: costly to produce but cheap to reproduce (sunk cost, zero marginal cost)
- But networks also have operational and maintenance costs (including billing)
- Another difference: networks can get congested

Features of communications market

- All data transport services are simply means of transporting bits at a given quality
- Can use this basic service for providing other value added services
- Statistical multiplexing => overbooking
  - Traffic is bursty
  - Economy of scales: larger network => more efficient multiplexing
- Flexible, multidimensional SLAs
- Exchange of signals on fast timescales => renegotiation
- Commoditized wholesale market
  - Internet is a “stupid” network, hence can be efficiently engineered
  - Also reason for its success
  - Intelligence at edges

Role of economics

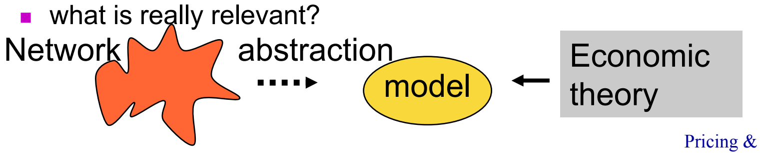
- Decentralized control mechanisms
  - Use price and congestion signals to provide incentives
- Engineering performance: in terms of utilization, delay, blocking, etc
- Economic efficiency: include the “value” that customers obtain from using the network
- Entities (users-customer, network) are rational, seeking to maximize there own benefit

Overprovision or control ?

- Overprovisioning possible in the core
- May be more difficult in metropolitan and even more so in access networks
  - Used by fewer customers
  - Much more costly than core
- May be impossible in wireless networks

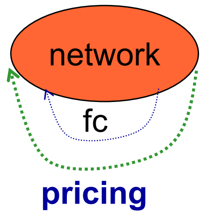
Some thoughts on charging …

- **There is no unique view on charging for network services**
  - Disparate models, contradicting proposals
- **There is no need for pricing network services!**
  - No congestion in the future
  - price only content
- **There is nothing new! (Economists did everything already)**
  - yes and no!
  - economists need simple models to work with => **abstraction**
  - what is really relevant?



Our view on charging

- **Charging is not only for making profits, but for**
  - improving network performance
  - providing **stability and robustness**
  - creating revenue
- **Charging should provide**
  - ***incentive compatibility*** *to users*
  - ***important information*** *to network control*
- **Charging should be**
  - simple but not simplistic
  - understandable
  - implementable
  - competitive



Network control and pricing

- Set of feasible services depends on network control mechanisms
- Economic incentives influence network control mechanisms
- Communication service contracts (Service Level Agreements - SLAs) provide substantial flexibility, and ability to exchange economic signals on fast timescale
- **Network control**: controls cell flows to guarantee contracts
- **Pricing**: controls demand in order to increase efficiency

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. universities

      charging for street-parking in Athens
  - Obtain information from users:
    - examples: special long-distance call packages in U.S.A. => their adoption is indicative of user's *future* behavior

Types of Charge

- There a four types of charge:
  - Fixed charge
  - Usage charge
  - Congestion charge
  - Quality charge
- A charge of a telecommunication service constitutes a combination of the above components, which may overlap

Coca Cola's dynamic pricing experiment

- Added *thermometer* to vending machine
- Automatically *raised prices* when weather was *hot*
- Rational:
  - a coke has more ***value*** to people during ***hot*** weather
  - *higher demand* during hot weather, hence *higher prices*

Back to *Coca Cola's* dynamic pricing experiment ...

Was it successful ?

- Prices didn't track congestion well...
- What they did:
  - increase of temperature ⇒ increase of price
- What the could have done:
  - decrease of buyer inter-arrival time ⇒ increase of price, or
  - decrease of supply ⇒ increase of price

➔ Method for detecting congestion

Incentives

- A charging scheme influences users' *demand* and behavior, according to the *incentives* it offers to the user, regarding how to maximise his *own utility* (benefit from service *vs* charge)

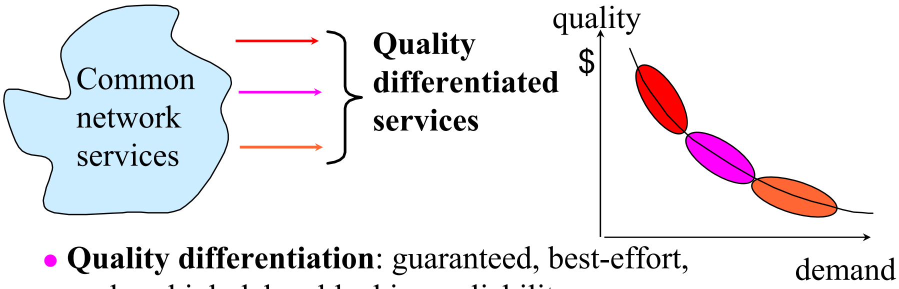
- Each individual user's behavior influences the *global* well-being (social welfare) of the society (users and network)

- A charging scheme is *incentive compatible* if individual user utility optimisation *also* results in social welfare optimisation

Incentives

- Flat rate versus usage charging
  - Example: all-you-can eat
- Time of day charging in telephony
- Dynamic pricing in an Internet Café
  - Fixed price per ticket
  - Normal & peak periods: duration depends on # of users
- Taxi tariffs: a+b*T+c*X, where
  - a,b,c: tariffs parameters
  - T: duration, X: distance
  - T,X mutually exclusive: if speed small then charge T, else X
  - Large b: incentive for driver to increase duration (drive fast between lights, and wait long time at lights)
  - During day when demand is high: make trips short, accommodate more people, and take advantage of fixed charge a

A proposal for pricing



- **Quality differentiation**: guaranteed, best-effort,
  - low-high delay, blocking, reliability, access
- Prices differentiate **quality** of service, **not content**
- Prices depend on **demand**, driven towards cost by competition;
- Price relation defined by **substitution**; proportional to
  - *effective bandwidths* for guaranteed services
  - *throughput* for best effort services

Single resource model

- Single link with capacity C, shared by N customers
- How should it be shared ?
- Solution 1: Each user can get C/N
- But what if some users have demand < C/N ?
  - Bandwidth is wasted
- Solution 2: fair sharing (allocate resources iteratively)
  - At each step t, allocate to each user C_t/N_t
  - Next step C_{t+1} =remaining bandwidth
- But all users do not value bandwidth equally…

Taking into account user utility

- User utility: $u_i(x_i)$
- Global planning problem:

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

- But, difficult to know all utilities

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- But, difficult to know all utilities
- Under conditions (utility is concave), the above can be solved distributed using prices and allowing each user *i* to solve $\max_{x_i} \{u_i(x_i) - px_i\}$
- Price p set such that $\sum_i x_i(p) = C$
- Demand function $x_i(p)$

Properties of approach

- Network does not need to know utility of all users
- Decentralized solution, each user acts to maximize their own benefit
- Sharing done by users, not internal network mechanisms
  - Network only provides "price" (=congestion signal)
- Incentive compatibility: best solution for each user maximizes aggregate utility (social welfare)
- Efficient (economic) resource utilization: capacity is used in full, by those who value it most

Network revenue and user surplus

- Network revenue $p\sum_i x_i(p) = pC$
- User surplus: $u_i(x_i) - px_i$
- Under no competition or regulation, provider might want to obtain all surplus
  - Take-it-or-leave-it offer: $u_i(x_i) - e$
  - Different price p_i to different users
  - Nonlinear prices (e.g. a+b*x)