Pricing the Internet

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Outline

- The growth of the internet
- The role of pricing
- Some pricing proposals
- Pricing in a competitive framework
- Conclusions

The Size of the Internet

- Public internet is considerably smaller than voice and private line networks (Odlyzko 1999)
- Voice network still dominates in carried load
- Data networks lightly utilized
  - Users value burstiness, peak bandwidth
- Growth (per year): Internet 100%, PL 20-30%, voice 10%, FR 100%

The Size of the Internet (Cont.)

network	bandwidth (Gbps)	traffic (TB/month)
US voice	375	43,000
pub Internet	150	5-8,0000
private line	400	4-7,000

Other public data networks: 80Gbps, 1000 TB/month

Data Networks and Congestion

network	utilization (average)	utilization (peak)
Local phone line	4%	10%
US long dist. voice	33%	70%
Internet backbones	10-15%	25%
Private line networks	3-5%	15-25%
LANs	1%	5%

Congestion and User Preferences

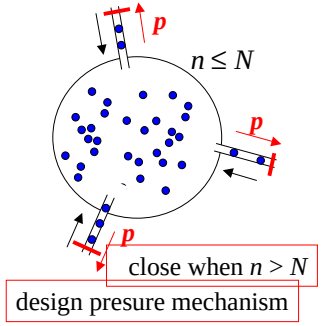
- Parts of the internet are highly congested
  - Public peering points, naps, maes
  - Feeder links that aggregate traffic into backbone
  - Transatlantic links (us->rest of the world)
- Bad performance is due to many reasons
- User preferences: low transaction latency
  - More transactional traffic than multimedia

The Evolution of the Internet

- Two directions:
  - Single service best-effort class, state-less, offers high quality through low utilization
    - Similar to evolution of lans, pcs
  - Multiple classes, state-aware, better utilized
    - Cost of control vs cost of bandwidth
- Internet economics will decide!

The Role of Charging

- Assume:
  - Finite capacity C
  - Minimum level of QoS
  - $\text{price} \downarrow 0 \Rightarrow \text{demand} >> C$
- Need some form of admission control
- Role of charging:
  - Flexible admission control
  - Users that need more can get more!!

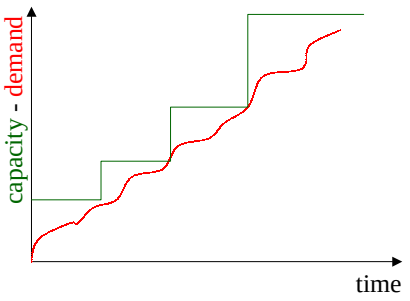


Charging vs Admission Control

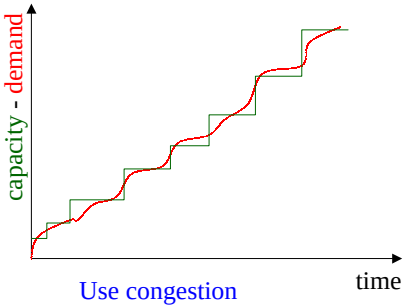
- Decisions made by users not network
- Flexible form of policing
- Fair allocation of resources
- Incentive compatible mechanism
- Increased stability and robustness
- Cost recovery
- Problems:
  - Internet technology: 'its not my problem'
  - Cost of charging
  - Reduces penetration of internet

The Continuously Expanding Model

- The demand and the network expand continuously
- Is there a need for charging for usage?



Keep network over-designed



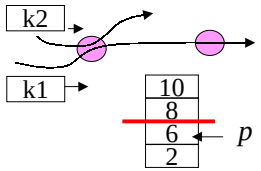
Use congestion
as a signal for expansion

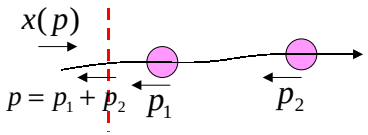
Some Questions

- How are prices constructed?
  - Regulation vs competitive markets
- Structure of prices?
  - Dynamic vs static
  - Flat vs usage-based
  - Service differentiation
- Who pays the bill?
  - Propagation of incentives

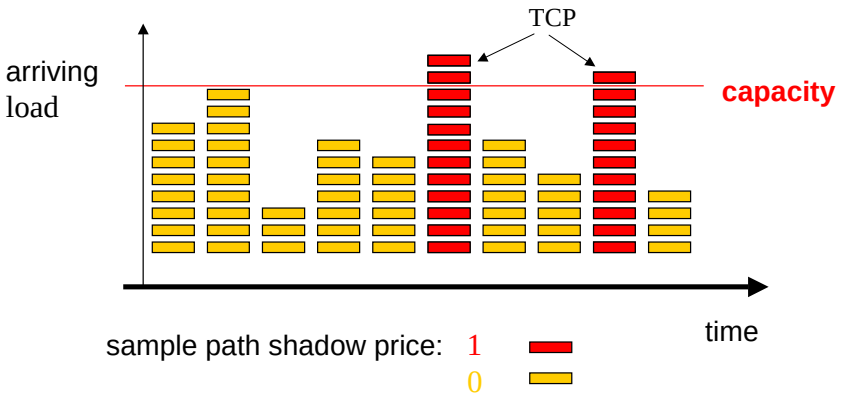
Dynamic Pricing

- Prices reflect congestion at network resources
- Flows determined by:
  - User's willingness to pay
  - Congestion prices inside the network
- Proposed methodologies: *many*
  - Smart markets (incentive-compatible auctions, mackie mason and H. Varian)
  - Proportional fairness (F.P. Kelly)



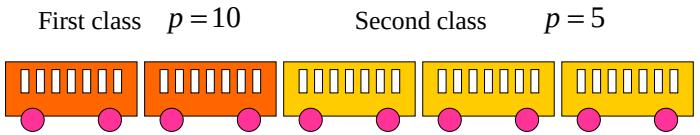


Sample Path Shadow Prices



Paris Metro Pricing

- Idea: create two logical networks, fix two different price levels (high-low), let users self-adjust (Odlyzko 1997)

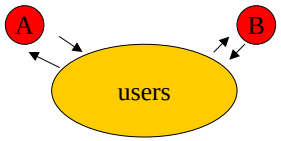


Differential quality (throughput) is the result of differential pricing

- no need for extra network mechanisms

Stability Under Competition

- Pricing shemes must be stable in a competitive market
- Various models of competition
  - Monopoly, oligopoly, perfect competition
  - Different results regarding price stability
- Game: provider A seeks to maximize revenue
  - Strategy: builds network of size C_A, sells services S_A, uses tariffs T_A
  - Find equilibrium solution

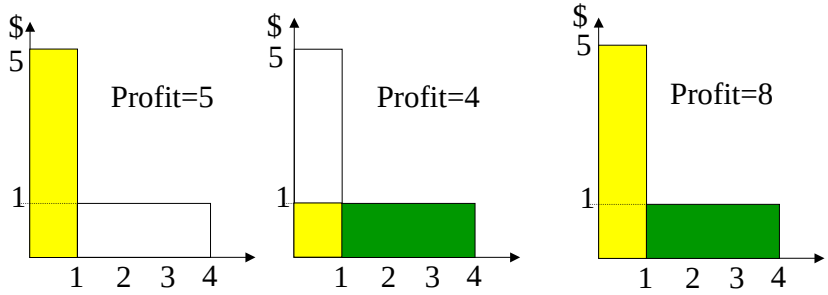


Some Results

- Perfect competition - monopoly:
  - Usage-based, market segmentation
- Oligopoly:
  - Trade-off between market segmentation and increased competition
  - Single service class might be preferable (R. Mason), unstable situations when 2 classes (PMP?)
  - Usage-based pricing not always optimal
  - Cost of charging might be very important

Market Segmentation: an Example

Sell a product to different customer types



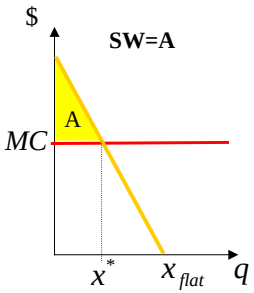
Price discrimination:
- **personalized pricing**
- **versioning**
- **group pricing**

Flat Rate Pricing

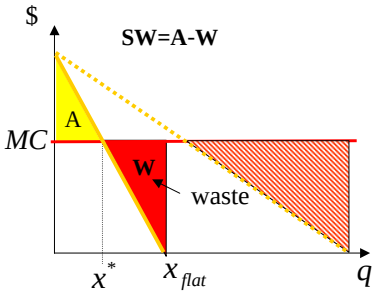
- Flat rate pricing is widely used because
  - Easy to implement, **some** users like it
- Problems with flat rate:
  - High social cost (produces waste)
  - Light users subsidize heavy users
  - Unstable under competition
  - Inefficient market segmentation
  - Generates lower income for providers
  - Lower benefit for most users (except the heavy ones)
  - Recent experimental results for internet pricing in INDEX experiment (UC berkeley)

Flat Rate Pricing (Cont.)

Assume network cost = $MC\ x$



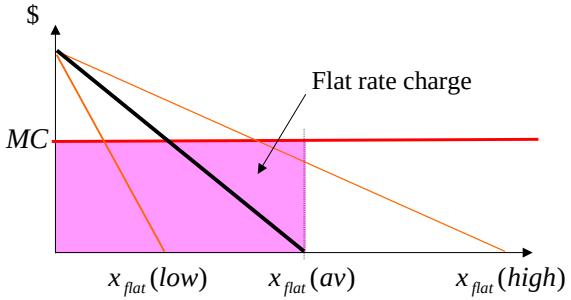
$p=MC$



Flat price ($p=0$)

Under flat pricing, users consume more than economically justifiable

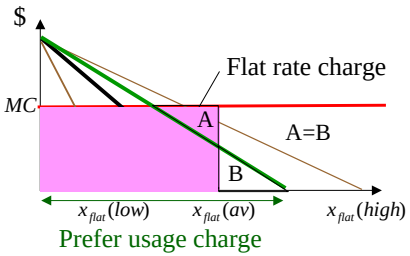
Cross-subsidization



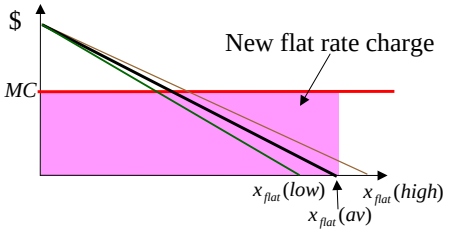
Low users will not participate => loss of revenue and SW
- solution: decrease flat fee (=> bad QoS, or constrain usage)

Cross-subsidization (Cont.)

Game: competitive provider with usage charge = MC



Prefer usage charge



=> eventually all customers prefer usage charge!

What will happen if the other provider switches also to usage charging?

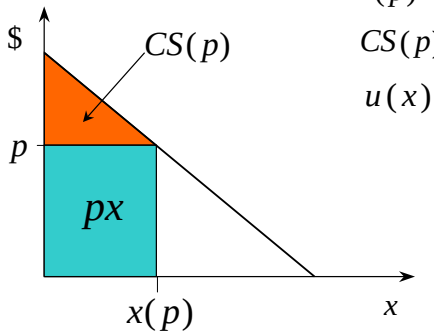
Conclusions

- Internet needs some form of flexible admission control to sustain quality levels
  - Intelligence pushed to the edges of the network
- Stability and robustness
- Prohibitive cost for introducing new tecnologies
- Pricing + service differentiation = competitive tool
- Many new open issues
- New business models
  - Bundling content with transport
  - Risk management
  - Intelligent software at the edges, optimization on behalf of users

Supplementary Slides

The Demand Curve

The demand curve:



$x(p) =$ quantity demanded at price p

$CS(p) =$ consumer surplus at price p

$u(x) = CS(p) + px$

= value of consuming x

Maximising Efficiency