Incentive Management in E-Commerce:
Specific Internet Issues

Yoav Shoham
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The online medium brings new incentive challenges

- Problems specific to online auctions:
  - Proxy bidding
  - Closing rules: Amazon vs. eBay
  - False-name bidding
- Controlling network traffic:
  - At the TCP level
  - At the user level
- Others we won't speak about:
  - P2P networks
  - recommender systems
  - …

Online Auctions I: Proxy bidding

- Both a convenience measure, and a solution to "sniping"
- Pushes auction towards a 2nd-price auction
- Concrete manifestation of the *revelation principle*

Online Auctions II: Closing rules

- eBay: hard deadline
- Amazon:

> *"We know that some bidders wait until an auction is about to close before placing a bid. Their goal is to slip in and seize the item before competing bidders have a chance to enter competing bids.*
>
> *At Amazon.com Auctions, we make sure competing bidders always have a chance--if only a small one. Our Going, Going, Gone feature ensures that interested buyers always have an opportunity to challenge last-second bids.*
>
> *Here's how it works: whenever a bid is cast in the last 10 minutes of an auction, the auction is automatically extended for an additional 10 minutes from the time of the latest bid. This ensures an auction can't close until 10 "bidless" minutes have passed."*

- Why snipe at all? Interesting analysis by Roth & Ockenfels …
  - Nonstrategic: Procrastination, search engine ordering,…
  - Strategic: avoid bidding wars, "collusive equilibrium"

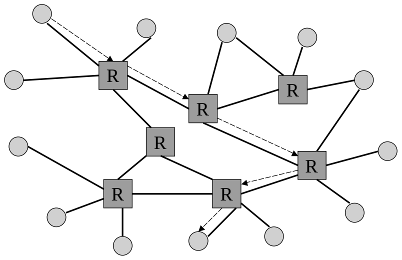
Online Auctions III: False identities

- Imagine a combinatorial auction with goods and the following two bids, each for {A}, {B}, and {AB}:
  - Agent 1: (6,6,12)
  - Agent 2: (0,0,8)
- Hence, in GVA Agent 1 will get the two goods, pay 8, and benefit 12-8=4
- But on the Internet, Agent 1 could create a false identity, Agent 3, and split his bid as follows:
  - Agent 1: (6,0,6)
  - Agent 3: (0,6,6)
  - Agent 2: (0,0,8)
- Hence, in GVA Agents 1 and "3" will each win and pay 8-6=2, and thus in reality Agent 1 will be paying 4, with an overall utility of 12-4=8
- What to do?
  - There is no false-name-proof combinatorial auction that is incentive compatible, (economically) efficient and individually rational
  - Some proposals for auctions that sacrifice efficiency

Beyond Auctions

Incentives at the infrastructure

Reminder: The infrastructure



TCP/IP at the end nodes

- A *flow* is broken into *packets*
- Each packet is marked with the flow ID, numbered sequentially, and annotated with the destination IP (perhaps with the help of a DNS).
- The first packet is sent to the gateway (initial) router as the first leg of the journey; additional packets follow it, first leisurely and then with increasing frequency.
- *Self correction:* The receiving end continuously sends back acks with the latest arrived packet #. If it received three acks in a row that the latest is #n, or #n "times out" (no ack within a specified period), TCP concludes that #n was dropped, and starts resending the flow from #n.
- *Automatic load balancing:* For every notice of a dropped packet TCP drops the sending rate by 1/2; for every newly ack'ed packet TCP increases the sending rate by *1/w*, where *w* is the current rate.

TCP/IP in the middle: a day in the life of a router

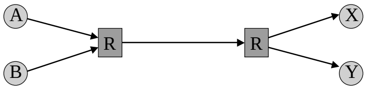
- Accepts packets, each with a destination IP address
- *Routing:* Using a (constantly updated) *routing table*, sends the packet along the link, unless there's congestion
- *Buffering:* If there's congestion, the message is maintained in a FIFO queue, unless the queue is full
- *Best effort:* If it's full the packet is unceremoniously dropped

TCP/IP and the tragedy of the commons

- Each user decides how many packets to send and how frequently
- These individual decisions jointly determine the congestion of the network
- The locally optimal action of increasing one's sending rate leads to global overuse of the network and thus a poor service to everyone

A game theoretic model: Prisoners' Dilemma

Player I: flow from A to X



Player II: flow from B to Y

Each player has two choices: T(CP) or U(DP)

	T	U
T	3,3	0,5
U	5,0	1,1

Key game theoretic concepts

- Games in matrix (aka normal, or strategic) form
- Nash equilibrium
- Dominant strategy
- (Social) efficiency

Some evidence that this is not idle speculation

- Close encounters in 1987, 1992
- The rise of UDP-based traffic
- Advent of “efficient” TCP implementations
- The multiple-connection trick

The jury’s still out on whether bandwidth is inherently scarce (plentiful fiber vs. hungry apps and bottlenecks at regional and local levels). But enough have worried about it to make some proposals…

The Situation

- What you’d like:
  - Nice users:
    - Play by the rules of TCP
    - Tell us how important each flow really is to them (email versus video, online heart surgery versus online Doom)
  - Smart routers:
    - Somehow give high priority packets of important flows
- What you have: Greedy, lying users and FIFO
- What you can do:
  - Charge the selfish folks
  - Change FIFO to some degree
- Such incentive engineering is called *mechanism design* (or *implementation theory*) in game theory

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RFC2309 of the IETF in 1998:
Two recommendations for improving congestion management

- Technological: From FIFO to other queuing schemes
  - Ex.: Fair queuing, RED (Random Early Detection), CHOKe *
  - Not our focus
- Economic: Charging usage fees, cleverly
  - Our focus

* Not all listed in the RFC

Changing FIFO alone is not enough

Shenker, *Making Greed work in Networks,* 1994

- Can’t achieve maximal efficiency without instituting some form of payments
- Replacing FIFO by a version of Fair Queuing does at least achieve fairness, and is also “learnable” quickly by a simple protocol

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Other arguments for usage fees, beside efficient use of network resources

- Quality of Service (QoS) guarantees (delay, throughput)
- People can discover their own utility function
- Not held hostage to obsolete technologies

Two pricing proposals

- Vickrey strikes again: Economic optimization
- Paris Metro Pricing: Psychological simplification

Vickrey strikes again
(Mackie-Mason & Varian, 1993)

- A fairly academic proposal, dubbed “smart market”
- Each packet has a “bid” field
- When network is not congested, no usage charge
- When it is congested, the highest bids are accepted up to the link’s capacity
- Prices change on a minute-by-minute basis
- The price is the “clearing price”, or the price just above the rejected bid
- This is exactly Vickrey pricing, generalizing 2^{nd}-price auction to the $M+1^{st}$-price auction, for M units of good.

Various criticisms

- Congestion information not available to end users
  - But see recent proposal by Gibbens and Kelley
- The willingness of users to pay is not enough to recover costs of network, and so is not that material
- Social optimality an overly simplistic criterion
- It’s unrealistic to assume that pricing schemes can be enforced universally
- The scheme requires a fairly radical change to the routing software, and in particular detailed accounting
- Doesn’t handle multicast
- …

A simple alternative: Paris Metro Pricing (PMP)
Odlyzko, 1998

- Divide the bandwidth into a few (e.g., 4) virtual channels
- Each channel will be identical, but charged differently
- Expensive channels will naturally attract fewer, more urgent flows
- Advantages:
  - Simple, predictable expense to end user
  - Relatively easy to implement (no metering)
- Disadvantage:
  - Inefficient use of the network
  - Indeed, not clear what precise quantity is being optimized

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Where do we stand on TCP

- Outstanding question: Is bandwidth an issue? Jury’s out
- Internet bodies urged to consider changing TCP for congestion management; changing FIFO more imminent than usage charging
- A fairly active area of research

Beyond TCP: Smoothing out Focused Loading

- Many users demand network resources at some focal time, predictable in advance
- Canonical example: long distance phone
  - people want to talk as early as possible, minimize cost
  - utility maximized when rates drop at 5 PM: network demand spikes
- Computer networks: load can be even more focused
  - sudden onset: TicketMaster server as tickets go on sale
  - deadline: IRS server just before taxes are due

Proposed Mechanisms

- We’ll discuss two explicitly; two more in the paper
- Why more than one mechanism? Many variables:

Type of equilibrium or strategy
Time cost of coordination phase
Time cost after coordination
Storage cost
Communication cost
Requires agent names?
Payment only after all slots?
Non-optimal equilibria exist?
Revenue increases if agents deviate?
Harmful collusion?
Irrational actions harm other agents?
Agents may have different *v* functions?

- To begin with, we’ll make two assumptions:
  1. all agents have the same preferences for slots
  2. mechanism designer knows these preferences

Mechanism 1 (a straw-man): Preselection

1. Decide if each slot will be free according to p
2. Each agent chooses a slot

Select p so that agents are indifferent between all time slots:

- i.e., $E[u_i]$ constant for all slots
- we'll call this probability distribution p^*

Preselection: Equilibria

- *Any* set of strategies is a weak equilibrium, e.g.:
  - agents randomize (load balancing)
  - agents pick the "best" slots deterministically: maximize z
    - this is a weak, optimal equilibrium
  - agents pick *same* slot deterministically: focused loading!
- Theorem: if
  - agents have identical utility functions
  - payoffs are *independent* of agents' moves

  then a strict, optimal equilibrium does not exist.

Mechanism 2: Collective Reward

1. The mechanism assigns agents "names" corresponding to slot numbers
2. Each agent chooses a slot
3. The mechanism computes p^*, and determines which slots will actually be free as follows:

- *count*(s): the number of agents given name s
- $d^+(s) = |count(s) - d(s)|$
- S: the set of slots which minimize d^+

$$p(s)=\begin{cases} p^*(s) & s\in S \\ 0 & s\notin S \end{cases}$$

Collective Reward: Equilibrium

- A strict equilibrium: a_i chooses slot *name*(i)
- All other agents play this strategy—a_i could:
  1. play the strategy too
     - d^+ is minimized by all slots
     - a_i gets the same utility regardless of her name
  2. select a different slot
     - a_i's slot will never be free
     - if expected utility for cooperation exceeds $v(bestslot)$, deviation is unprofitable, and φ is a strict equilibrium

Two More Mechanisms

- Bulletin Board
  - agents coordinate with each other by broadcasting their intended slot choice
  - agents get free slots according to p^* iff their distribution is optimal; otherwise no slots are free
  - strict, optimal equilibrium
- Discriminatory
  - agents are assigned slots by the system
  - each agent gets the slot free according to p^* iff he chose the assigned slot; otherwise he pays m
  - dominant strategy: unique, optimal equilibrium

What else you should read

Required:

- *Last-minute bidding…,* Roth & Ockenfels
- *Recommendation on Queue Management and Congestion Avoidance in the Internet,* RFC 2309, Braden et al., pp. 1-10 (easy non-mathematical reading)
- *Making Greed Work in Networks*, Shenker, sections 1,2,5 (feel free to skim sections 3,4 which give the formal model and analysis)
- *Pricing the Internet,* Mackie-Mason & Varian, all except appendix
- *Paris Metro Pricing for the Internet*, Odlyzko, all except appendix (which you can read if you want a quantitative analysis of a particular instance of PMP)

Optional:

- *Incentive mechanisms for Smoothing…*, Leyton-Brown et al.,
- *Pricing Computer Networks: Reshaping the Research Agenda,* Shenker et al. (essentially a critique of a "smart market" approach)
- *Resource Pricing and the Evolution of Congestion Control,* Gibbens and Kelly (influential but technical recent proposal, based on RED, that shows how to implement smart-market-like scheme efficiently)
- *Greedy Combinatorial Auctions*, Lehmann et al.