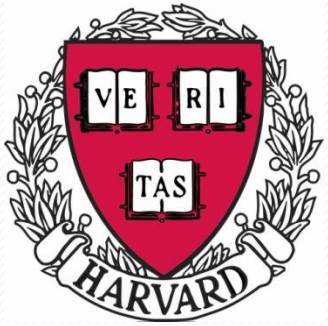
Security Games in Online Advertising: Can Ads Help Secure the Web?



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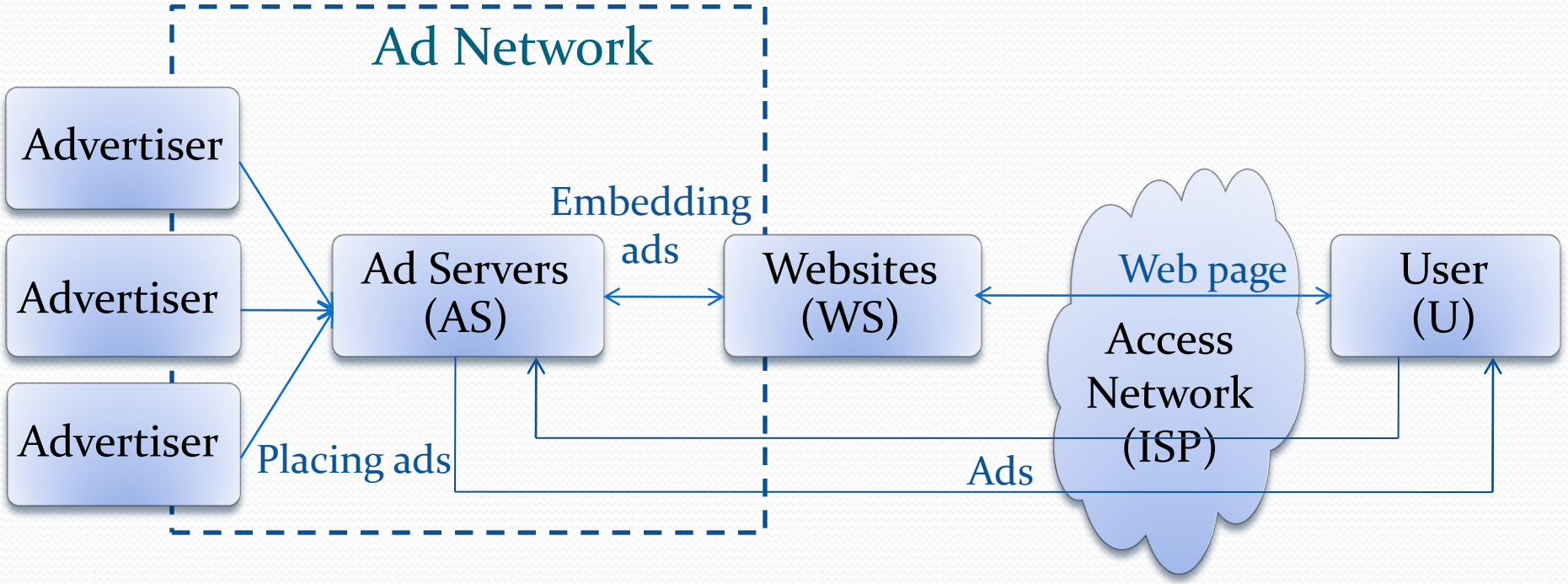
Internet Economy

- Online Advertising:
  - The main Internet business model
  - Revenue in 2009 in the US is $22.4 billion
  - Sponsors free services and applications
- What happens if one meddles with it?

Online Advertising System



Role of ISPs

- Traditional role:
  - Provide Internet access to end users
  - Forward the communication in compliance with Network Neutrality Policy
- New requirements
  - Data retention legislations
  - Increase costs and require investing into new technologies

- How will ISPs obtain a return on investment?

Recently Reported Cases

- Growing number of ISPs injecting own content into web pages [1][2]
- Third party ad companies partnering with ISPs
  - e.g., Adzilla, Phorm, NebuAd

[1] C. Reis et al. **Detecting In-flight Page Changes with Web Tripwires**, NSDI 2008.
[2] B. April, F. Hacquebord and R. Link, **A Cybercrime Hub**, August 2009.

ISPs in Online Advertising Business

- ***Non-cooperative ISP*** – diverts part of online ad revenue by performing attacks on online advertising
  - E.g., injecting ads into the content of web pages on-the-fly
- ***Cooperative ISP*** – collects and provides information about users' online behavior with the goal of improving ad targeting
  - Generates revenue by charging for users' profiles

Problem Statement

- Study the effect of strategic ISPs on the Web
  - Model the behavior of ISPs and economic incentives in online advertising systems
  - Analyze mutually dependent actions of ISPs and Ad Servers (AS)

Related Work

- Online advertising fraud
  - The best strategy for ad networks is to fight click fraud [1]
- Incentives to increase the security of the Web
  - Users' choice: Investment in security or insurance mechanisms [2]
- Our model introduces a new strategic player – the ISP

[1] B. Mungamuru, S. Weis, H. Garcia-Molina, **Should Ad Networks Bother Fighting Click Fraud? (Yes, they should.)**, Stanford Technical Report, July 2008.

[2] J. Grossklags, N. Christin, J. Chuang, **Secure or insure?: a game-theoretic analysis of information security games**, WWW 2008.

Outline

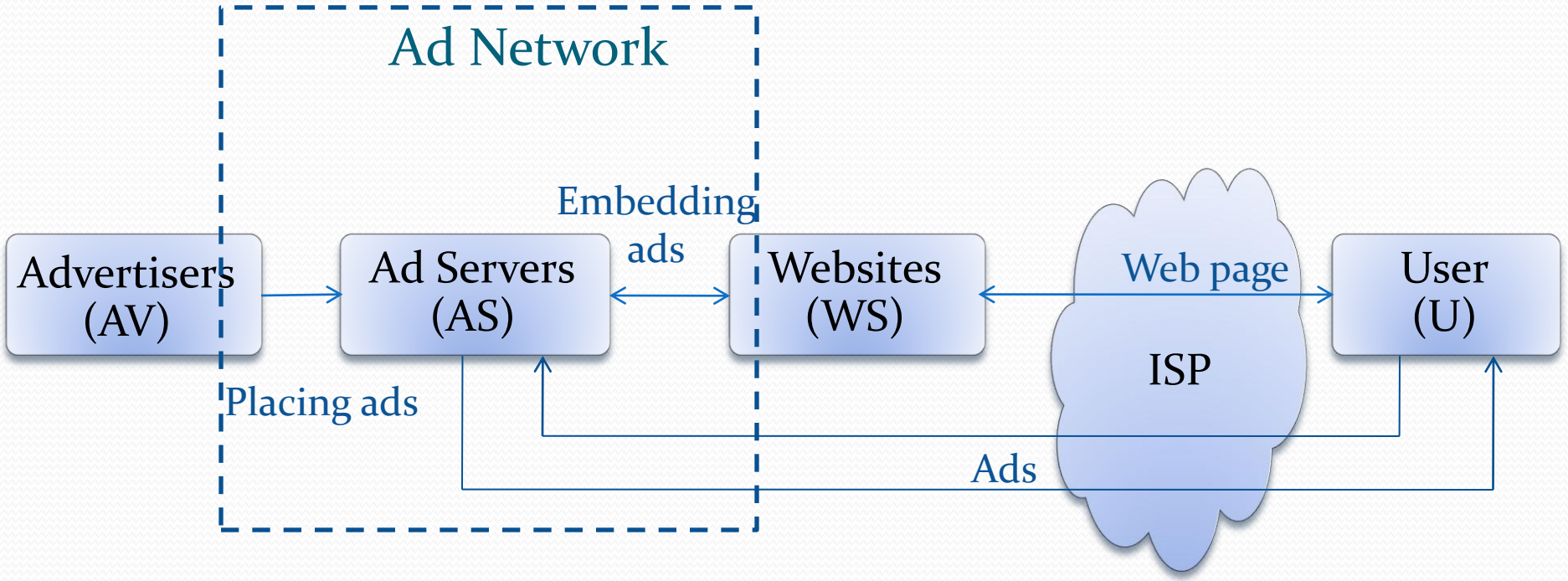
I. Strategic behavior of ISPs

II. Game-theoretic Model

III. Analysis and Results

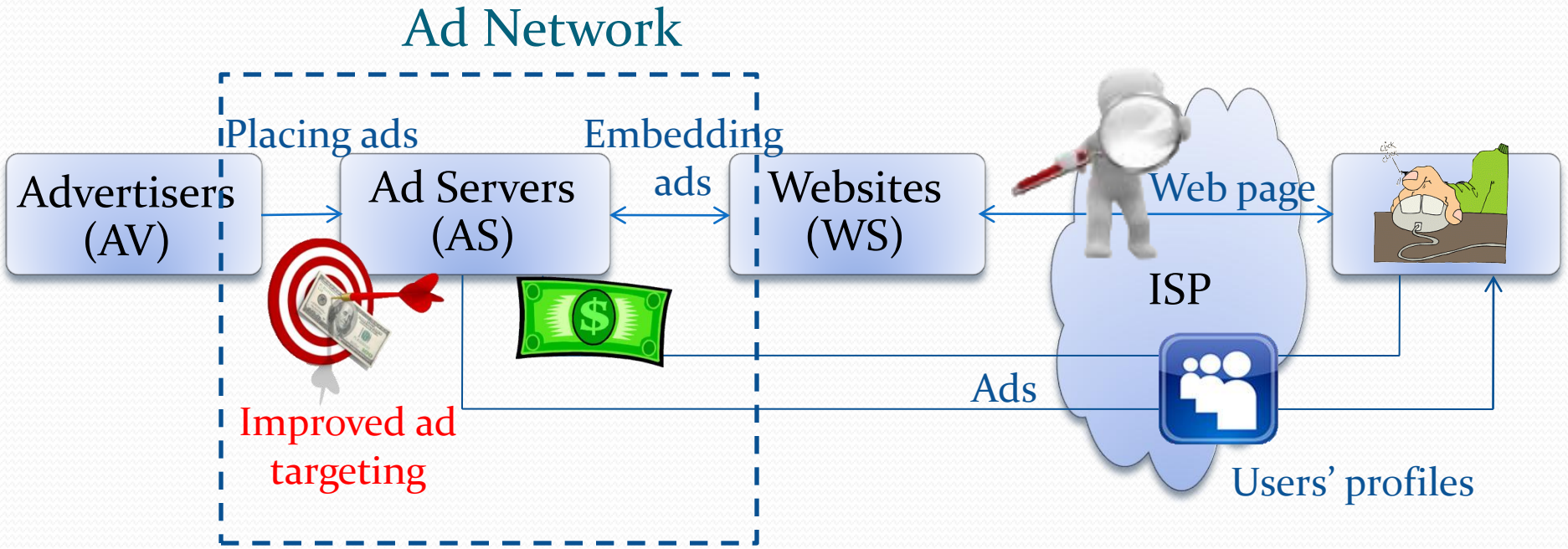
Nominal Mode

- **ISP**: Abstain (A) – forwards users' communication
- **AS**: Abstain (A) – serves online ads upon users' requests



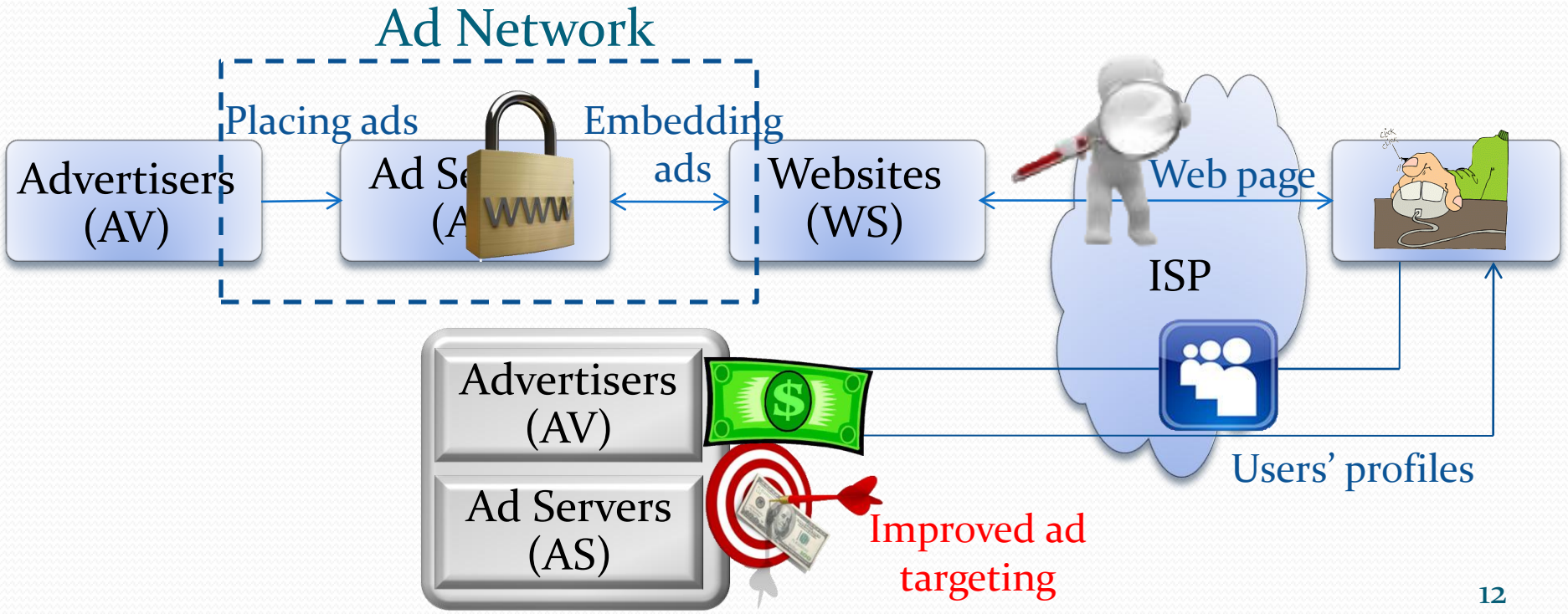
Cooperative Mode

- **ISP**: Cooperate (C) – shares the collected users' profiles to help AS improve ad targeting
- **AS**: Cooperate (C) – shares a part of its revenue with the ISP



Non-Cooperative Mode

- **ISP**: Divert (D) – diverts a fraction of the ad revenue from the AS
- **AS**: Abstain (A) – serves online ads upon users' requests
  Secure (S) – secures the website



Non-Cooperative Mode

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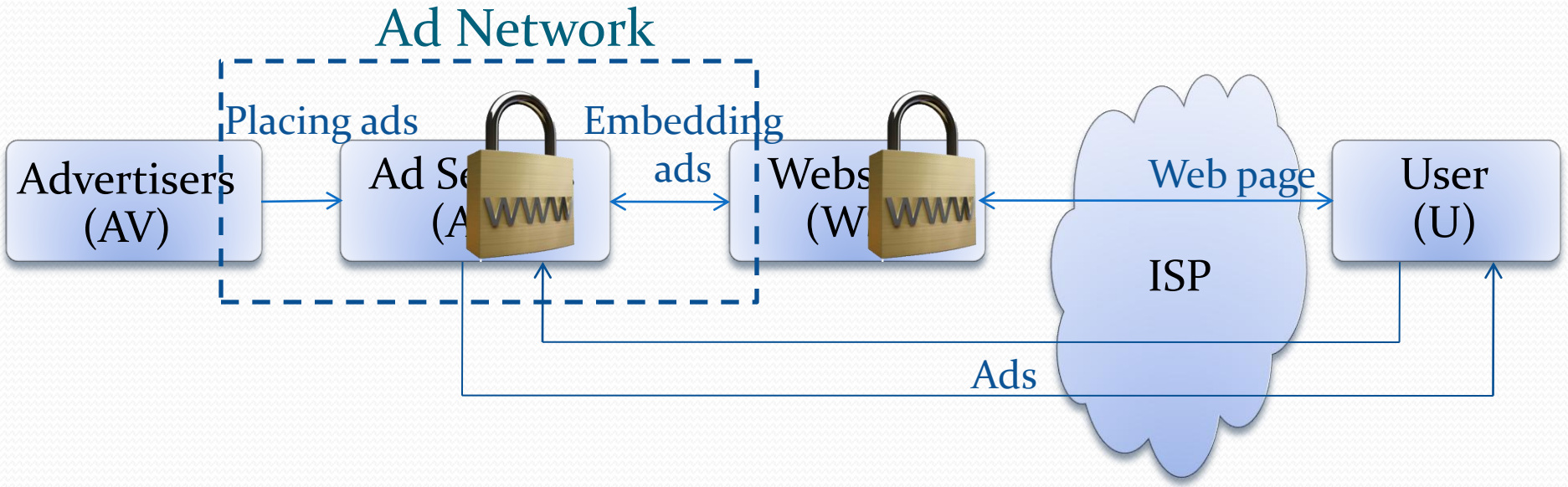


Game-theoretic Model

- Behavior of **ISP**s:
  - **Abstain (A)** – forwards users' communication
  - **Cooperate (C)** – shares the collected users' private info to help improve ad targeting
  - **Divert (D)** – diverts a fraction of ad revenue from the AS
- Behavior of **Ad Servers** (AS):
  - **Abstain (A)** – serves online ads upon users' requests
  - **Cooperate (C)** – shares a part of its revenue with the ISP
  - **Secure (S)** – secures a website to prevent loss of ad revenue

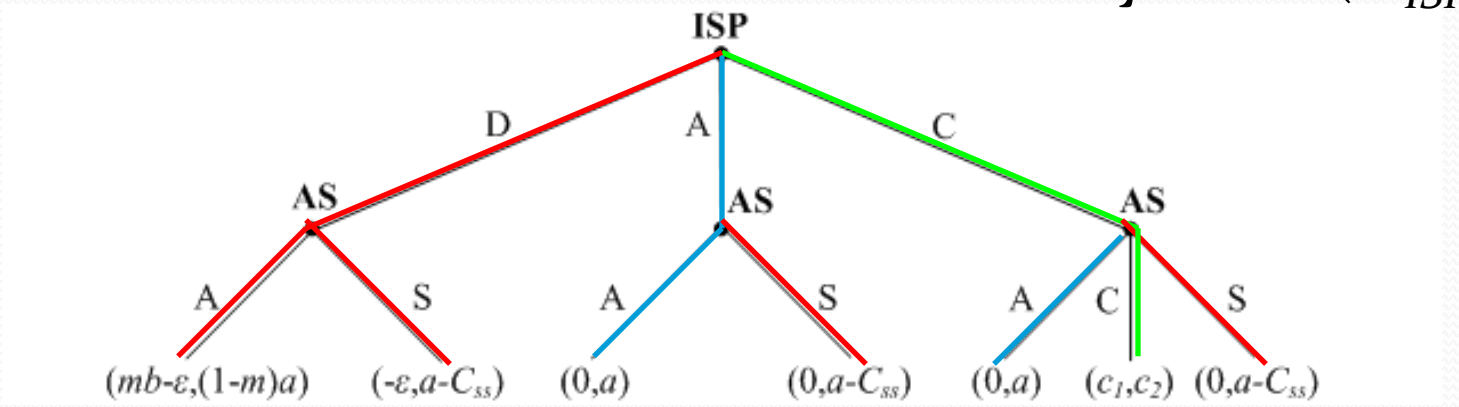
The Game

- Dynamic, finite **multi-stage** game $G=\{P,S_A,U\}$
- Set of players: $P=\{ISP, AS\}$
- Multi-stage game: *Single stage game* played for n stages
- Total payoffs over n stages= Σ(payoffs at each stage)
- Complete and perfect information
- Game is modeled for a single website
- Identify Subgame Perfect Nash Equilibrium (SPNE)

Single Stage Game

- If a website is **not secured**

Payoffs = (U_{ISP}, U_{AS})



- a – *AS*'s total payoff in the nominal mode
- c_1, c_2 – *ISP*'s and *AS*'s total payoff in the coop mode
- m – Fraction of clicks *ISP* diverts
- ε – Cost of diverting clicks
- b – *ISP*'s per fraction revenue when diverting clicks
- C_{ss} – One-time cost of securing a website

Single Stage Game (cont'd)

- If a website is **secured**

Payoffs = (U_{ISP}, U_{AS})

- a – *AS*'s total payoff in the nominal mode
- c_1, c_2 – *ISP*'s and *AS*'s total payoff in the coop mode
- m – Fraction of clicks *ISP* diverts
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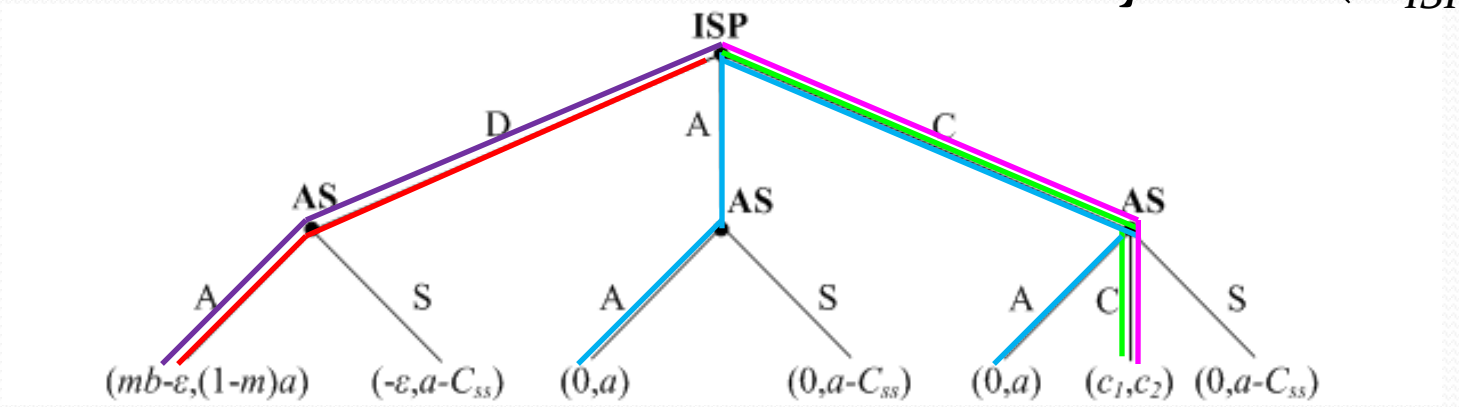
Solving the Game

- Example: n=1

Payoffs = (U_{ISP}, U_{AS})



Case 1: $ma \geq C_{ss}$, $c_2 > a$ — *outcome: (C,C)*

Case 2: $ma \geq C_{ss}$, $c_2 \leq a$ — *outcome: (A,A),(C,A)*

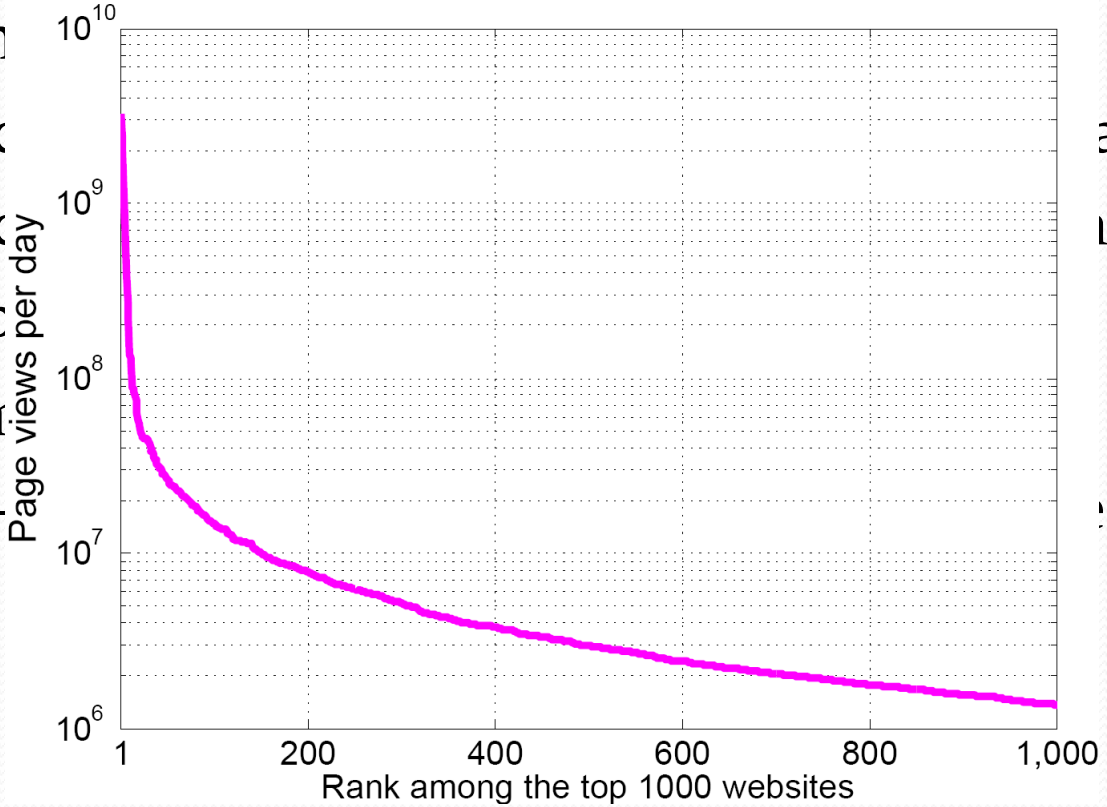
Case 3: $ma < C_{ss}$, $c_2 \leq a$ — *outcome: (D,A)*

Case 4: $ma < C_{ss}$, $c_2 > a$, $c_1 \geq mb-\varepsilon$ — *outcome: (C,C)*

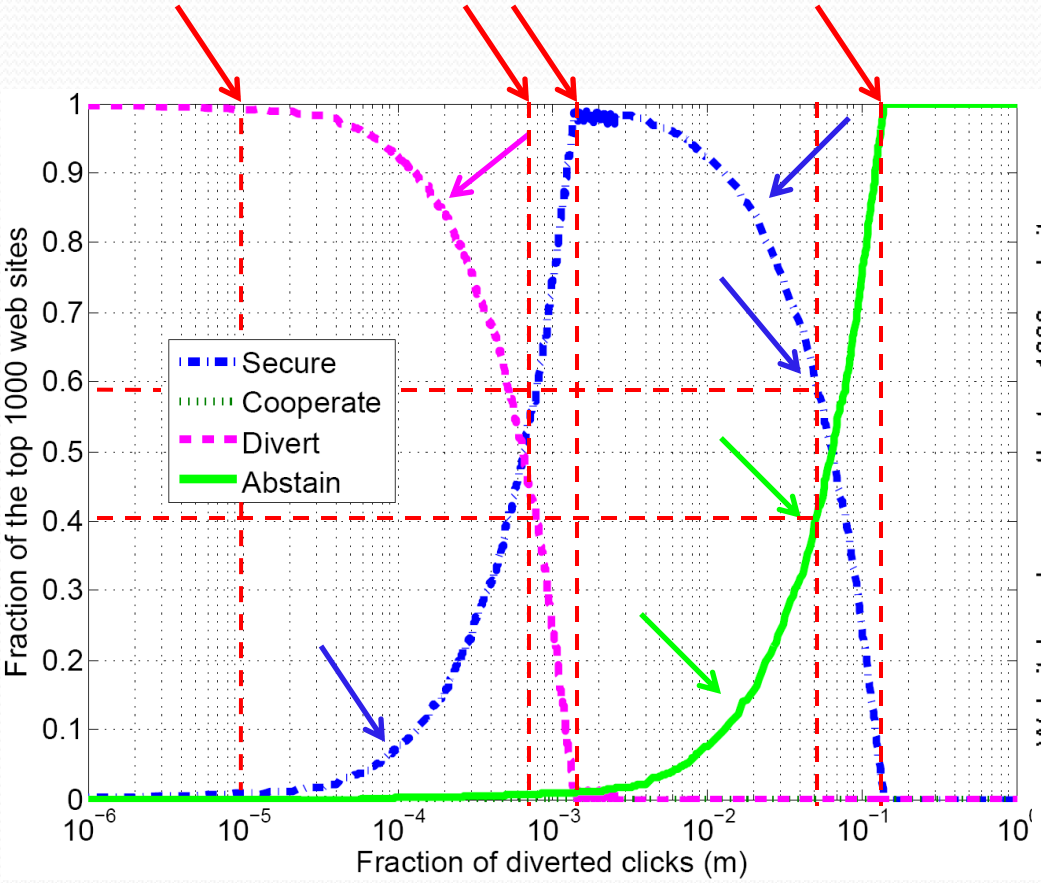
Case 5: $ma < C_{ss}$, $c_2 > a$, $c_1 < mb-\varepsilon$ — *outcome: (D,A)*

Evaluations on a Real Data Set

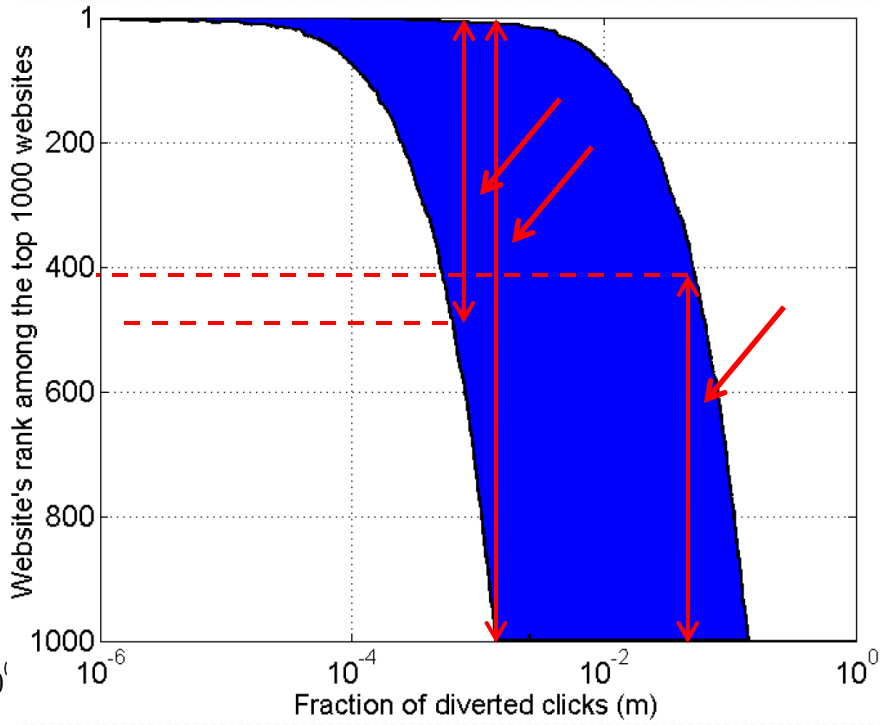
- Top 1000 most popular websites in June 2009
  - based on the data of page views [*Compete.com*]
- Param
  - Frac ative ISP (m)
  - Frac g (l)
  - Imp
- Assun
  - C_{ss} – and HTTPS at the



Non-cooperative Scenario



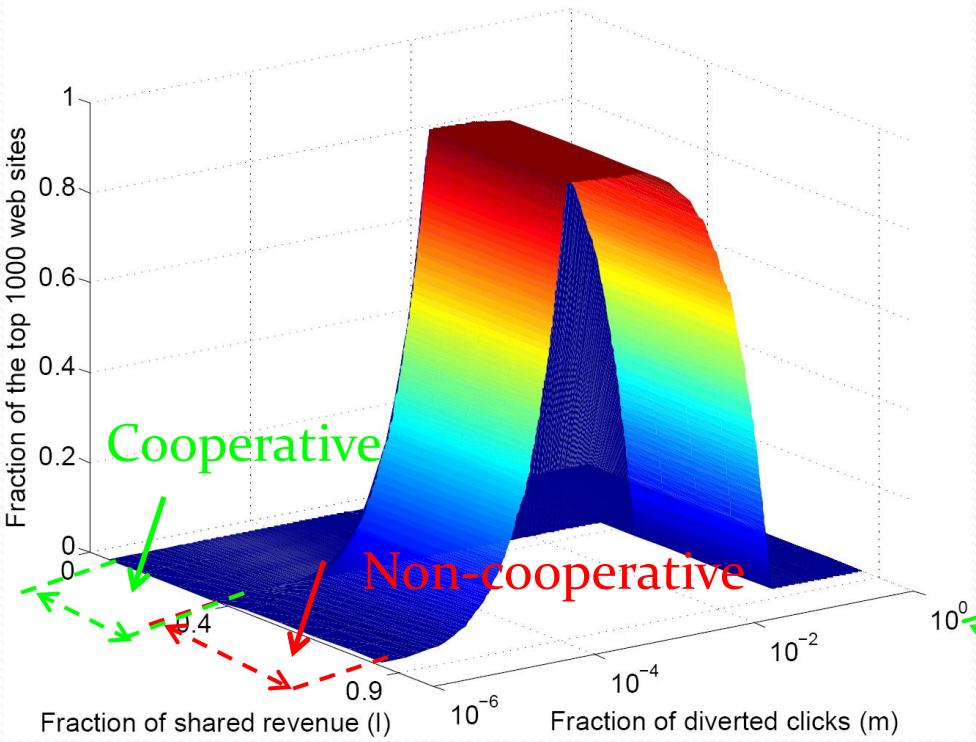
Outcomes of the multi-stage game for the top 1000 websites



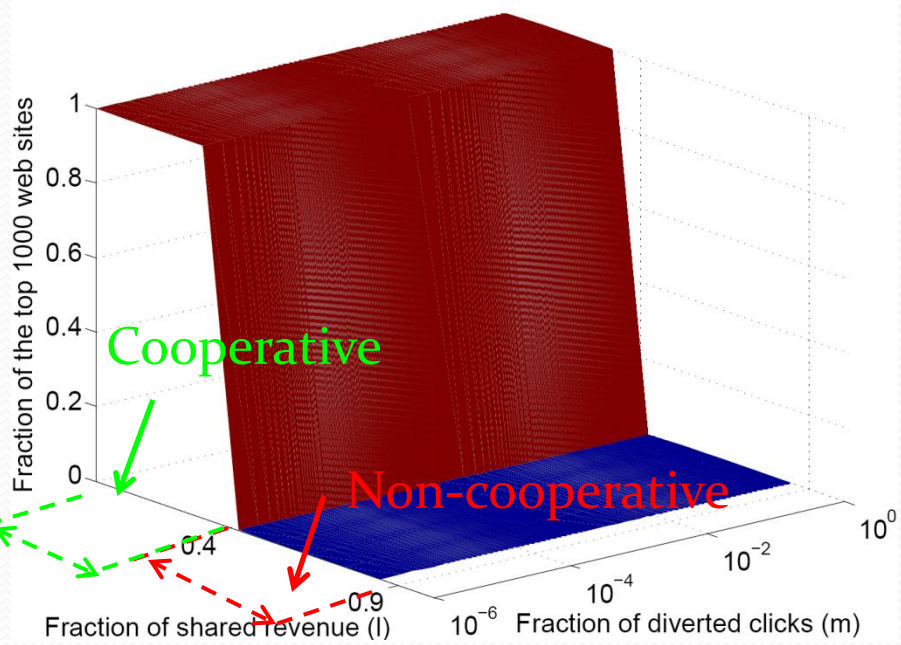
Secured websites (secure if $ma > C_{ss}$)

Effect of the Parameters

- Fraction of shared revenue when cooperating (*l*)



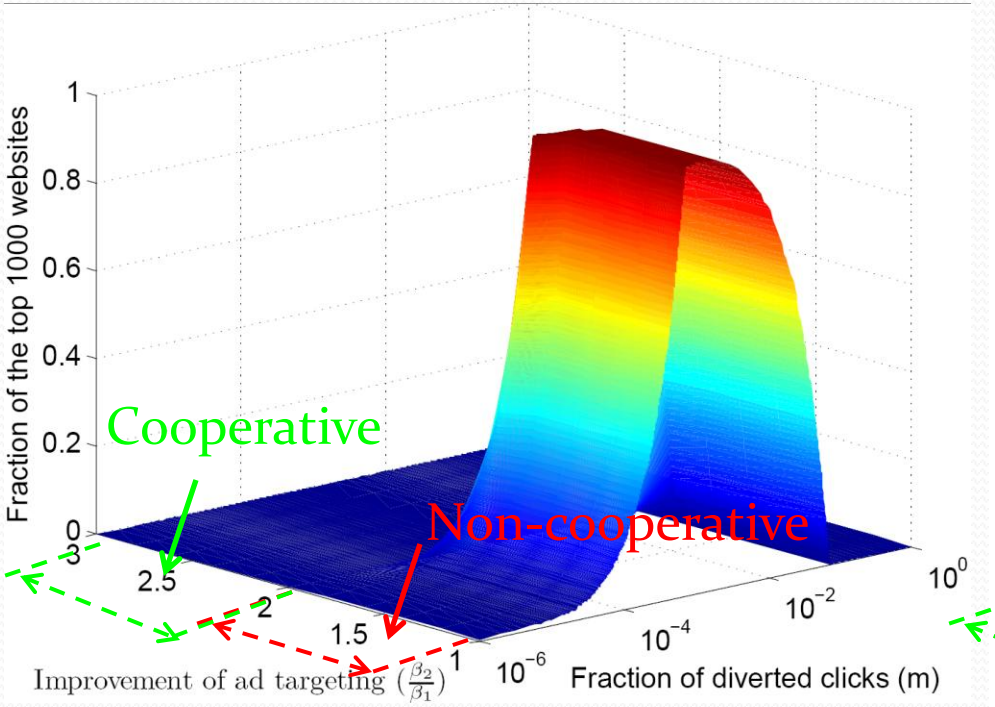
Secured websites



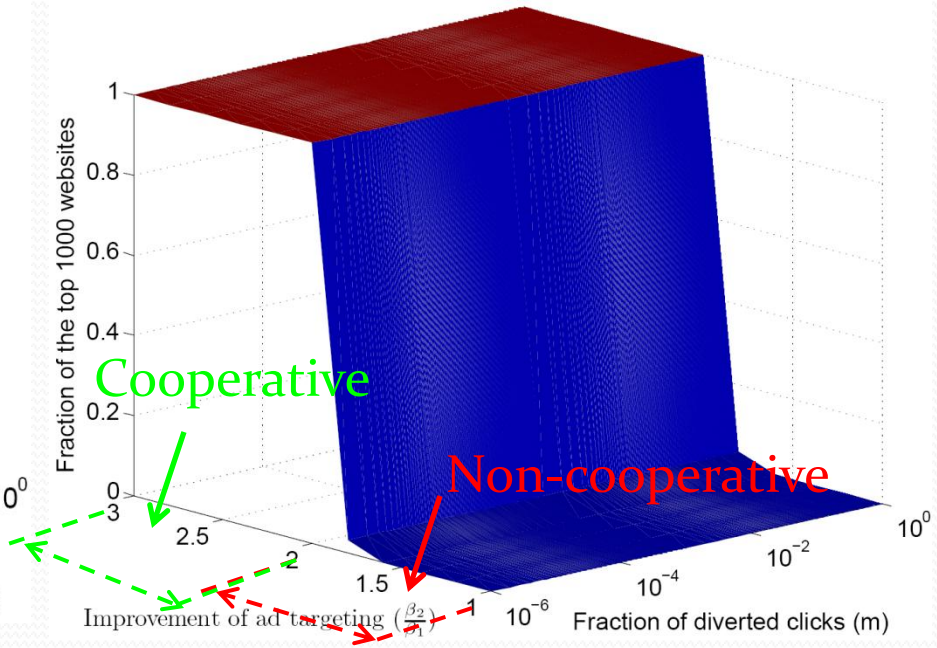
Cooperation achieved

Effect of the Parameters (cont'd)

- Improvement of ad targeting (β_2/β_1)



Secured websites



Cooperation achieved

Conclusion

- Novel problem of *ISPs becoming strategic participants* in the online advertising business
- Studied the behavior and interactions of the ISPs and ad networks
- Applied game-theoretic model to the real data
- Effect on the Web is *positive in both cases*:
  - Cooperative ISPs: - users receive better targeted ads
    - ISPs and ad networks earn more
  - Non-cooperative ISPs: - improved Web security
    - the most important websites secured first