Self-Interest-Driven Incentives for Advertisement Dissemination in Autonomous Mobile Social Networks

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AUTONOMOUS MOBILE SOCIAL NETWORKS

- Formed by mobile users who share similar interests and connect with one another using their mobile phones or portable tablets
- Exploits opportunistic, free, short-range radio connections, in contrast to web-based online social networks

ADVERTISEMENT DISSEMINATION

- Dissemination of personalized ads
  - coupons, deals, newsletters, product catalogs, and extra show tickets
- Each node can be an ad provider or a receiver or both
  - A provider generates ads: small local retailers, yard sale owners, and flea marketers
  - A receiver wishes to receive ads in one or multiple categories
  - Ads are disseminated from a provider to interested receivers directly or indirectly
- Ad dissemination via mobile social networks is highly effective, since the interaction among mobile users are closely correlated to their social groups and behaviors

SELFISHNESS AND INCENTIVES

- Selfish nodes
  - Reluctant to consume its energy, storage, and bandwidth resources for assisting others
  - Refuse to carry any ads other than the ones interested by itself
- Incentive scheme is imperative to stimulate nodal cooperation and attract more participants
  - Credits: virtual currency; each node owns some initial credits
  - Pay credit: source pays credits to disseminates its ads
  - Earn credits: intermediate node(s) earn credits for delivering ads
- Assumptions
  - Nodes are rational: neither consume their resources to help nor to maliciously attack others
  - Security is out the scope of this work: strong authentication that supports verification of identities of nodes

RELATED WORK

- Selfishness in MANET [15]-[18]
  - Do not apply under opportunistic communication
- Data sharing and distribution in delay-tolerant networks (DTN) [22]-[28]
  - All assume nodal cooperation
- Selfishness in DTN
  - Incentives for peer-to-peer DTN communications [20,21]
  - Incentives for data pulling [8]-[10]
    - Receivers are beneficiary and pay for delivery services
  - Incentives for data pushing [This work]
    - One-to-many: e.g., ads from a source to multiple receivers
    - Source must pay credits to intermediate nodes for data delivery service

CHALLENGES

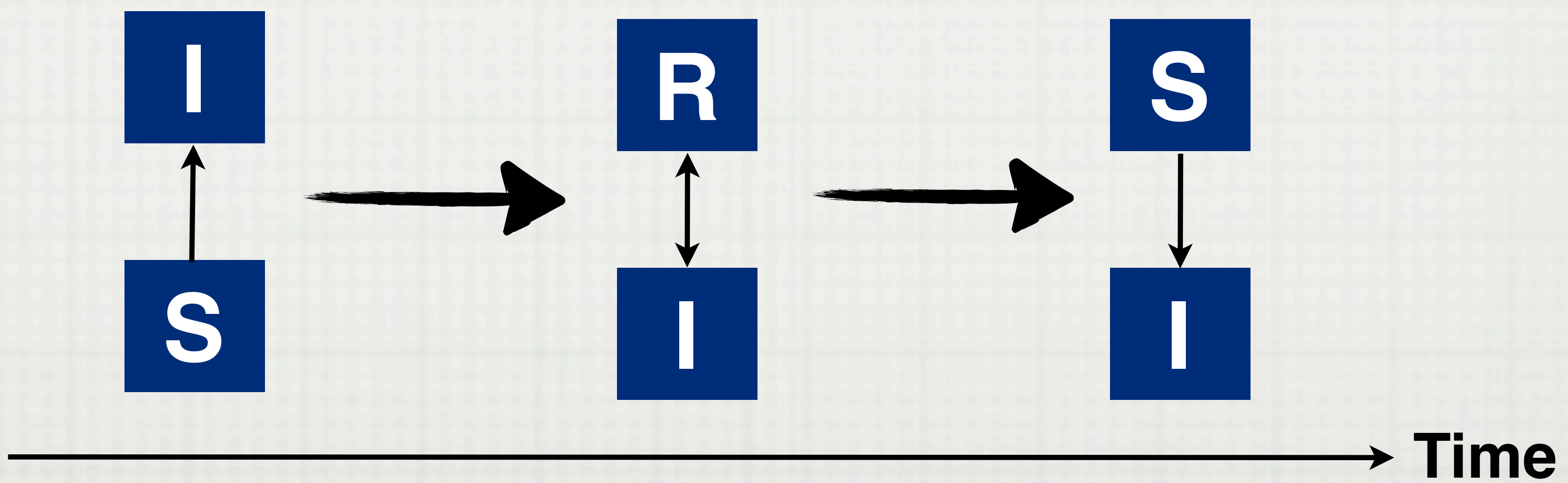
- Stems from DTN-like opportunistic communication
  - A routing path is nondeterministic
  - Source doesn't know how many nodes will involve in packet delivery and which nodes it should pay for
  - Challenging for data pushing where source pays
- Further complicated by packet duplication common in DTN
  - A packet often desired by multiple nodes with same interest
  - Only one (first) copy per receiver should be paid
    - Multiple copies of a packet delivered to the same receiver

PROPOSED SOLUTION

- Self-Interest-Driven (SID) Incentive Scheme
- “Virtual checks” to eliminate the needs of accurate knowledge about whom and how many credits ad provider should pay
  - Source doesn’t pay upfront credits but loads a “virtual check” in ad packet
  - Face value of check (α_p): the amount of credits the ad provider is willing to pay for each ad delivered to an intended receiver
  - Maximal deliveries (γ_p): the maximum number of receivers to whom the provider intends to send the ad
  - $\alpha_p \times \gamma_p$ indicates the maximum number of credits the provider would like to pay for disseminating the advertisement, which must be limited by the total available credits at the provider.

PROPOSED SOLUTION

- If a node delivers an ad to a receiver, the latter signs the check and authorizes the latter as the owner of the signed check
- When a node that owns a signed check meets the ad provider that issues the check, it requests the provider to cash the check



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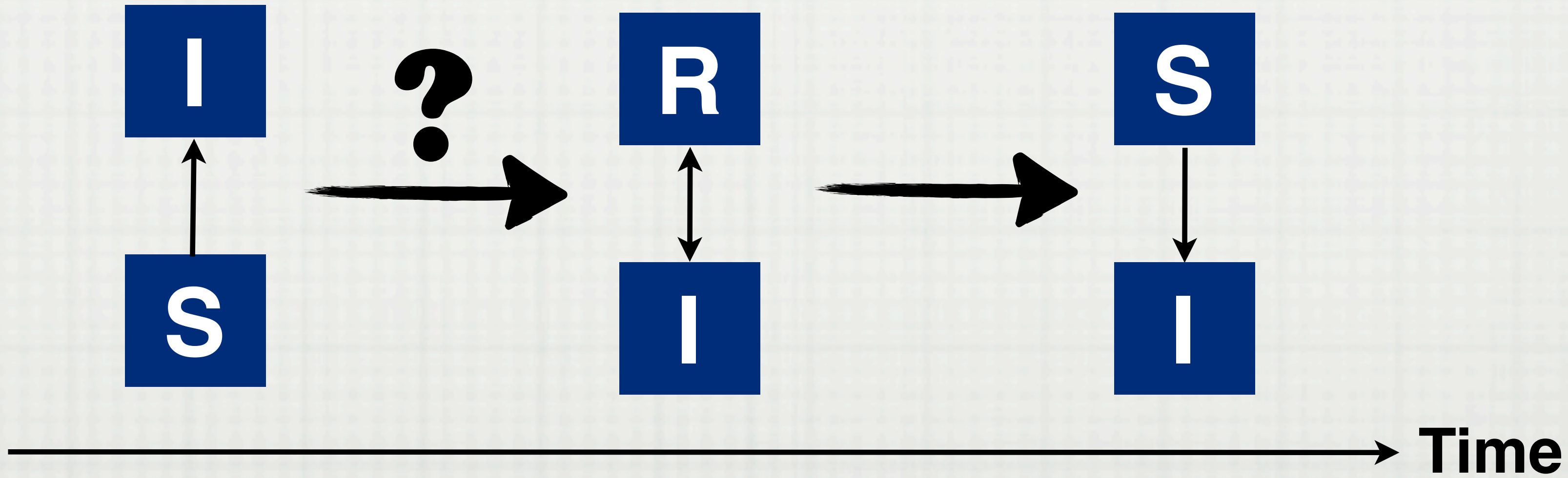

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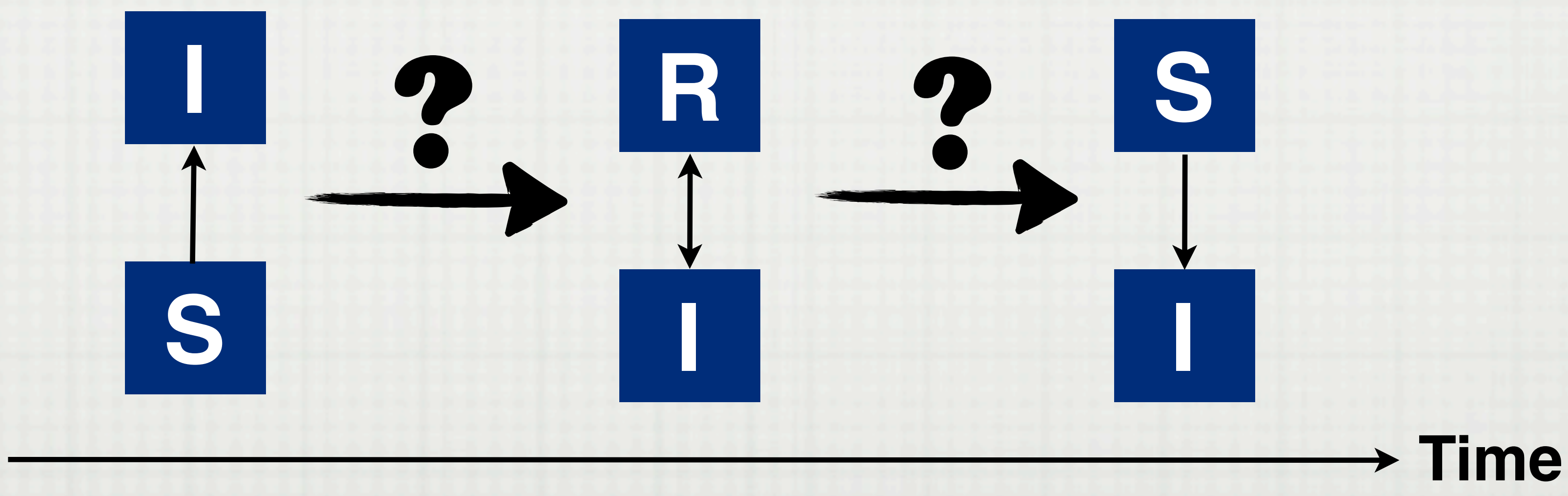
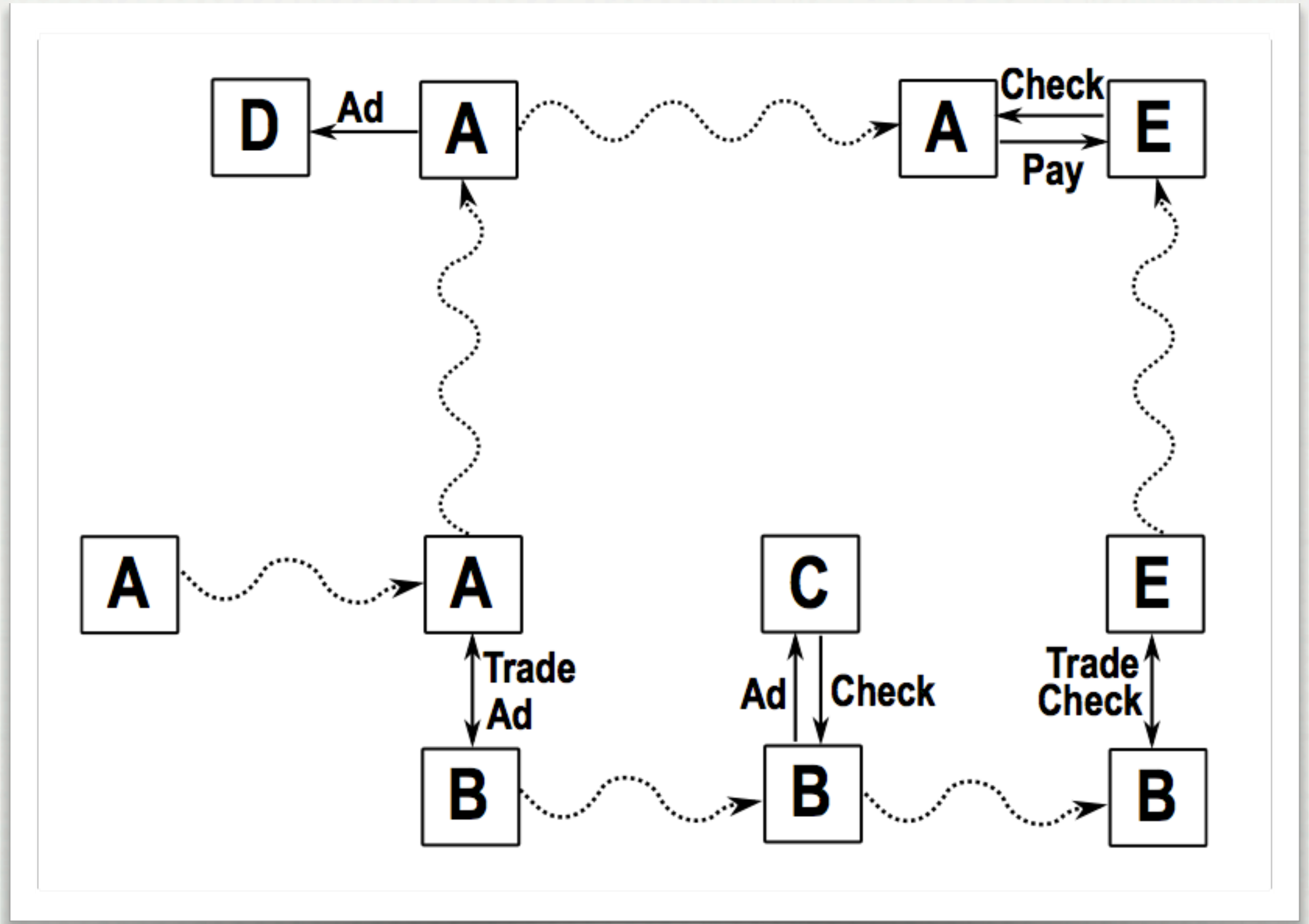


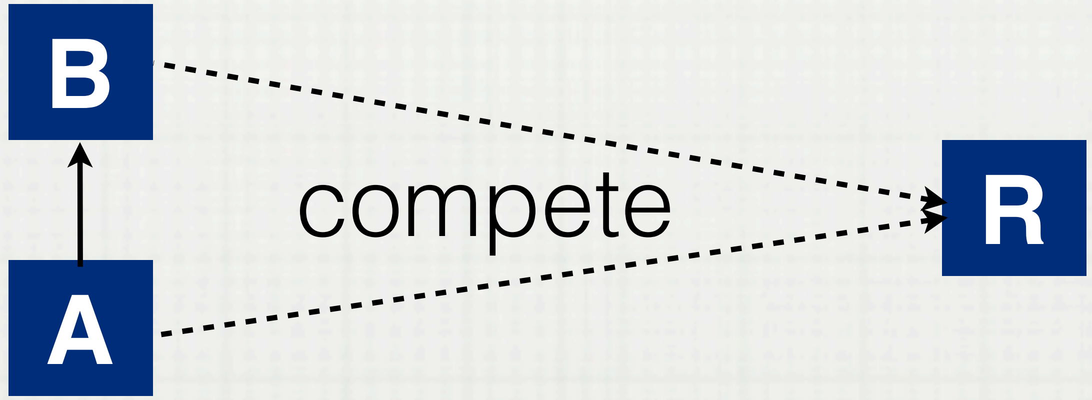
PROPOSED SOLUTION

- Allow nodes to trade ads and signed checks



PROPOSED SOLUTION

- Question: how to decide which ad or signed check be traded?
  - Selfishness: a node always tries to maximize its own benefit, which however may hurt the interest of the other node



- During the packet exchange, the nodes have conflicting interests
- Proposed solution
  - Properly define value (i.e., virtual rewards) of ads and checks
  - Formulate a two-player cooperative game to optimize the trade that increases the total values of both nodes

APPRAISAL OF AD AND CHECKS

- R_n^q: *Packet Virtual Reward* signifies the value of Ad Packet q to Node n --- how many credits (on signed checks) Node *n* would gain if it trades in Packet *q*
  - α_q : face value of the check included in the ad packet
  - ξ_n^i: ad category contact likelihood (ADCL), the likelihood for Node n to meet receivers (i.e., chance to earn signed checks)

$$R_n^q = \alpha_q \times \xi_n^i$$

- C_n^c: *Check Virtual Reward* indicates the value of Signed-Check c to Node n

$$C_n^c = \alpha_c \times \rho_n^c$$

APPRAISAL OF AD AND CHECKS

- ADCL intrinsically depends on the aggregated direct and indirect contact likelihood with receivers.
- η_n^i: direct contact likelihood of Node n with receivers in Ad Category i.
  - Initialized to zero
  - Updated at every contact with a receiver in Ad Category i or a timeout event, whichever comes first

$$\eta_n^i = \begin{cases} (1-\epsilon_1)[\eta]_n^i + \epsilon_1, & \textbf{Contact,} \\ (1-\epsilon_1)[\eta]_n^i, & \textbf{Timeout.} \end{cases}$$

APPRAISAL OF AD AND CHECKS

- $\hat{\eta}_n^i$: indirect contact likelihood of Node n with receivers in Ad Category i.
  - Initialized to zero
  - Updated at every contact with a node that is not a receiver in Ad Category i or a timeout event, whichever comes first

$$\hat{\eta}_n^i = \begin{cases} (1-\epsilon_2)[\hat{\eta}]_n^i + \epsilon_2 \eta_k^i, & \textbf{Contact,} \\ (1-\epsilon_2)[\hat{\eta}]_n^i, & \textbf{Timeout} \end{cases}$$

- Since the direct transmission and two-hop relaying are independent, we have the ADCL of Node n in Ad Category i

$$\xi_n^i = 1 - (1 - \eta_n^i)(1 - \hat{\eta}_n^i)$$

SELF-INTEREST GAIN

- Assume Node n meets and trades packets with another node
  - Let Φ_n and $\hat{\Phi}_n$ be the set of ad packets owned by Node n before and after the trade
  - Self-interest gain that Node n achieves by trading ad packets

$$s_n^a = \sum_{p \in \hat{\Phi}_n} R_n^p - \sum_{p \in \Phi_n} R_n^p$$

- Self-interest gain that Node n achieves by trading ad checks

$$\tilde{s}_n^c = \sum_{c \in \hat{\Psi}_n} C_n^c - \sum_{c \in \Psi_n} C_n^c$$

COOPERATIVE GAME MODEL FOR TRADING PACKETS AND CHECKS

- To maximize their own benefits, nodes often ask for different packets/checks to trade. How to satisfy both?
- Formulate bargaining interaction between nodes as a two-player cooperative game
  - Each player chooses its strategy, i.e., a set of packets or checks that it wants to get
  - The gain of one player depends on strategies chosen by both nodes
  - Must benefit both nodes
  - Unique and fair Pareto optimal point
  - Standard method to obtain optimal strategy that maximizes

$$(\hat{s}_n, \hat{s}_k) = arg \max_{(s_n, s_k) \in S} (s_n - d_n) \times (s_k - d_k)$$

COOPERATIVE GAME MODEL FOR TRADING PACKETS AND CHECKS

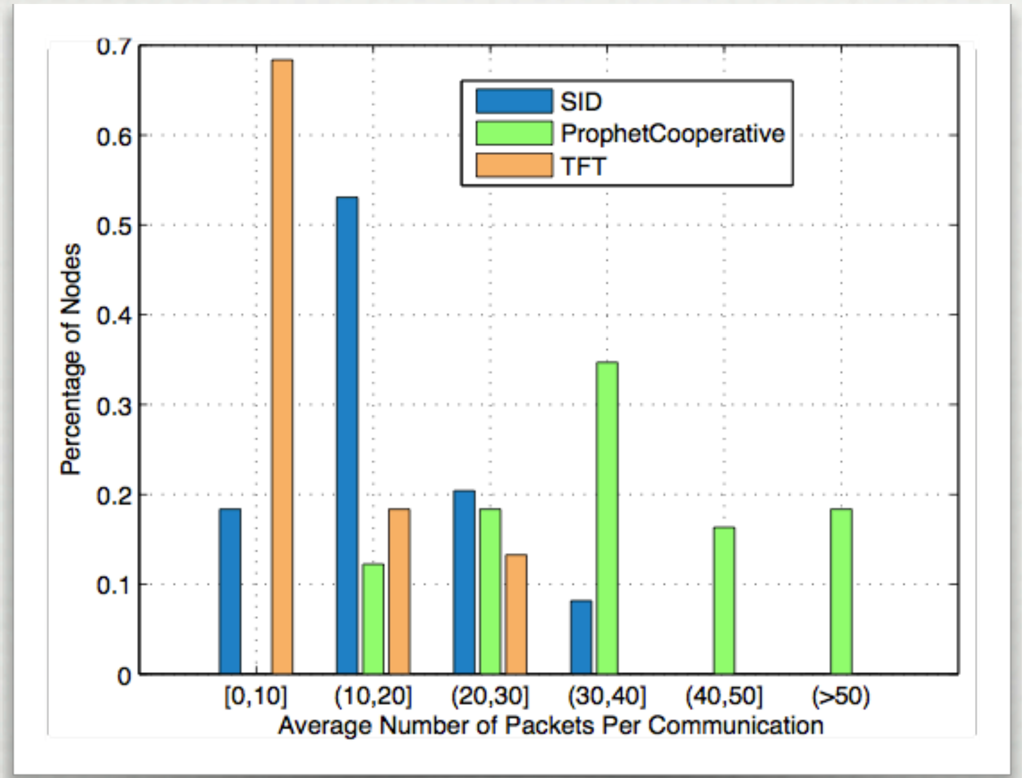
- Distributed protocol
  - Two player game implemented in a distributed protocol
- Properties:
  - Convergence: the convergence of the trading process is upper bounded, as the gain monotonously increases (no bargain deal will be reached without mutual benefits)
  - Optimality: achieves network-wide Pareto optimality at the convergence in a static network
  - Symmetry: the trading nodes have the same solution

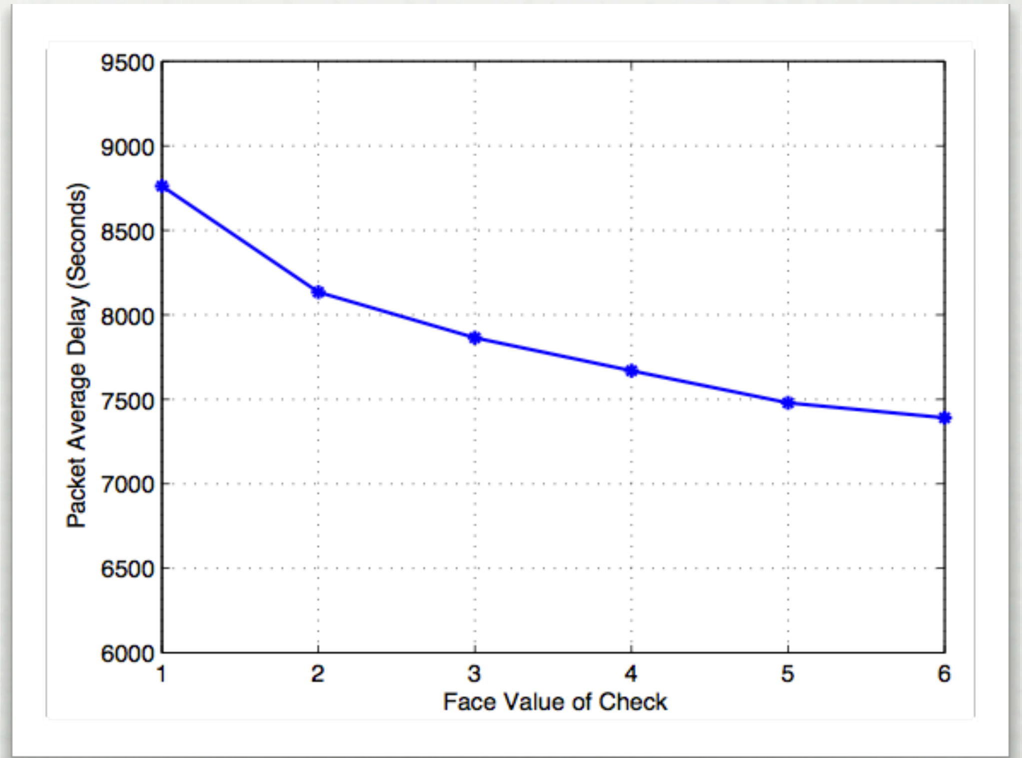
SIMULATIONS

- Simulation Setup
  - Cambridge Haggle trace [34]: 98 iMotes and Bluetooth devices for about 3 days
  - UMass DieselNet trace [35]: 37 buses for about two weeks
  - Thirty ad categories
  - A provider generates one ad packet every 15 minutes (in average) in a random category
  - A node is interested in receiving ads in 5 randomly chosen categories
  - Initial credits of 100
- Competing Algorithms:
  - PROPHET [33] is chosen as the baseline for comparison
    - "ProphetSelfish"
    - "ProphetCooperative"
  - Pair-wise tit-for-tat (TFT) [21]

SIMULATIONS RESULTS

	Delivery Rate	Average Delay	Overhead
ProhetSelfish	0.31	21598s (5.9h)	1
ProphetCooperative	0.78	4533s (1.25h)	19
TFT	0.71	17587s (4.88h)	6
SID	0.83	8078s (2.24h)	3





CONCLUSIONS

- Unique challenge for incentive provisioning in autonomous mobile social networks due to opportunistic communication
- Proposed a Self-Interest-Driven incentive scheme
  - “Virtual checks” to eliminate the needs of accurate knowledge about whom and how many credits ad provider should pay
  - Both ad packets and signed virtual checks can be traded between mobile nodes
  - define virtual rewards for ad packets and virtual checks, and formulated nodal interaction as a two-player cooperative game
- First incentive approach for one-to-many data pushing in opportunistic networks