Incentive-Aware Data Dissemination in Delay-Tolerant Mobile Networks

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Outline

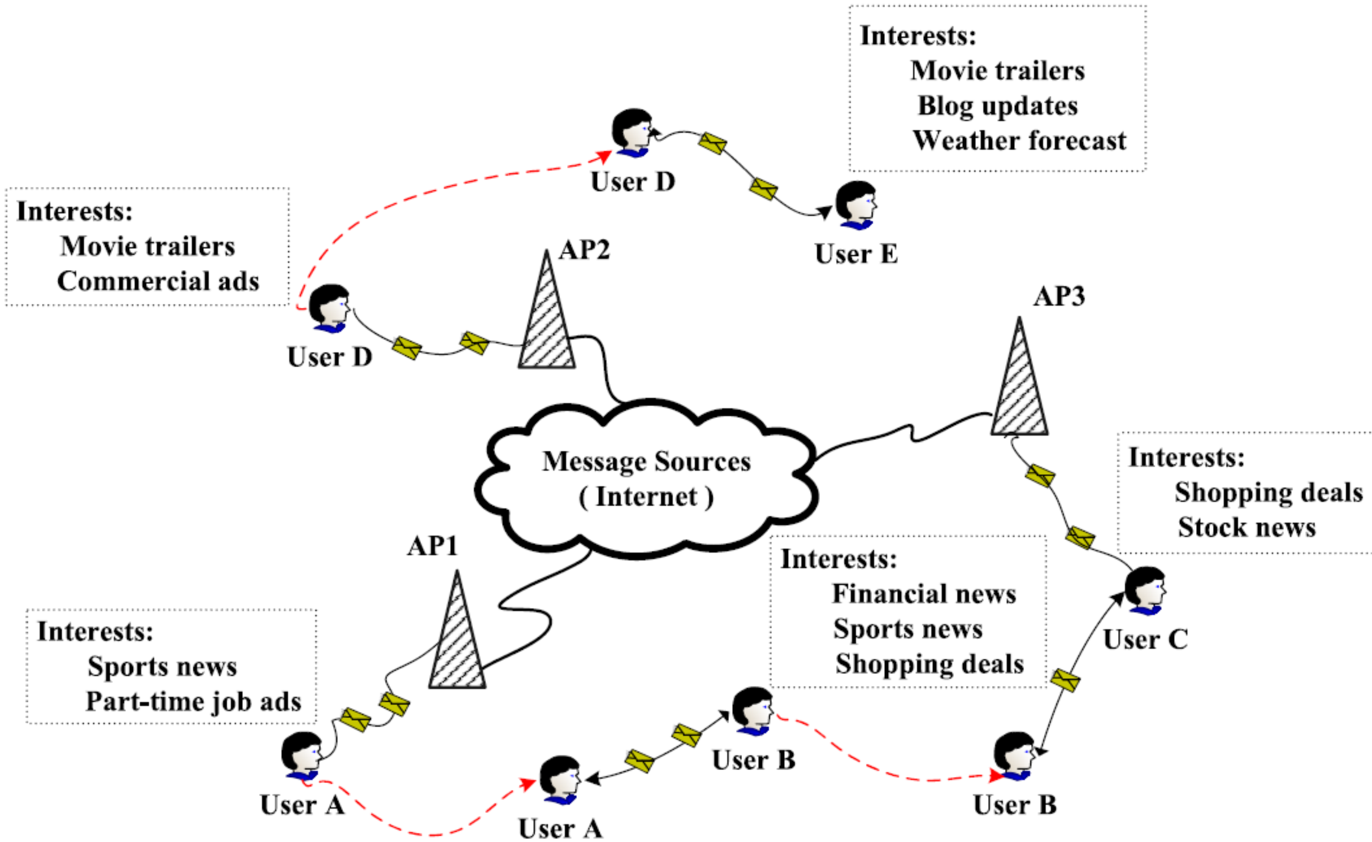
- Introduction & Motivations
- Challenges
- Design Basics
- Proposed Incentive-Aware Scheme
- Simulations
- Conclusions

Introduction

- This work centers on data dissemination in a mobile wireless network.
  - Portable devices establish an intermittently connected mobile network ,using short range radios.
    - cell phones
    - PDAs
    - laptops
  - Data to be disseminated fall into a range of interest types.
    - local weather forecast
    - community event alerts
    - commercial advertisement

Introduction

- An example of data dissemination scenario



Motivations

- Behaviors of nodes
  - Cooperative
    - voluntarily carry others' messages
  - Selfish
    - refuse to forward others' messages
    - only carry its own interested messages
    - save its own resources

- How to stimulate selfish nodes to participate into message forwarding and improve network performance?

- An incentive scheme is imperative to enhance nodal cooperation.

Challenges

- Poor end-to-end connections in delay tolerant network.
- A given message may be desired by multiple interested users.
- Multiple copies are created for a message.
- A receiver may receive multiple copies but only reward the first deliverer.
- How to evaluate the possible value of a message and maximize its benefit.

Contributions

- An incentive mechanism was proposed to promote nodal cooperation.
  - Credit is adopted for rewarding.
  - Intermediate nodes messages exchange based on the estimated values of data messages.
  - Game theory model is developed to solve the exchange process.

Design Basics

- Definitions
  - An interest
  - Source of messages of an interest type
  - Sink of messages of an interest type
  - Credit
  - Effective interest contact probability (EICP)-- *EICP of Node n in Interest i represents the likelihood that Node n contacts a sink of Interest i directly or indirectly.*

Design Basics (cont')

- How to calculate EICP
  - Direct contact probability of Node n in Interest i

$$\vartheta_n(i) = \begin{cases} (1-\alpha)\vartheta_n(i) + \alpha & \text{Contact} \\ (1-\alpha)\vartheta_n(i) & \text{Timeout} \end{cases}$$

  - Indirect contact probability of Node n in Interest i

$$\xi_n(i) = \begin{cases} (1-\beta)\xi_n(i) + \beta\vartheta_k(i) & \text{Contact} \\ (1-\beta)\xi_n(i) & \text{Timeout} \end{cases}$$

  - EICP

$$\chi_n(i) = 1 - (1 - \vartheta_n(i))(1 - \xi_n(i))$$

Design Basics (cont’)

- $C^m(i)$ -- *duplication degree of Message m in Interest i*
  - Indicates the number of copies a message has. Split-based approach is adopted to estimate this value.
- $A^m(i)$ -- *message appraisal of Message m in Interest i*
  - Indicates the number of potential receivers of that message.
- Rewarding policy
  - If Node n receives a message that matches its interests from Node m, the former rewards one credit to the latter.

Design Basics (cont’)

- $R_n^m(i)$ -- *expected credit reward of Message m in Interest i at Node n.*

$$R_n^m(i) = A^m(i) \times \chi_n(i) / C^m(i)$$

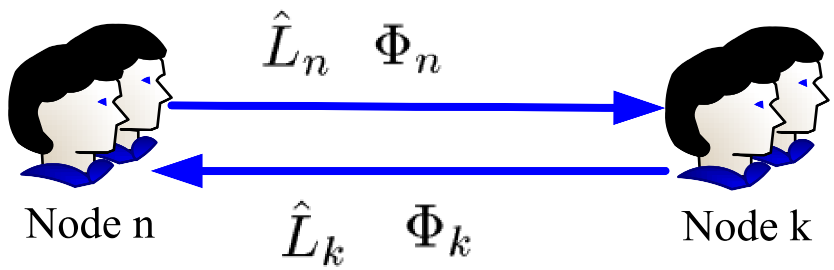
- U_i -- *Utility function of Node n.*

$$Max \quad U_n = \sum_{i=1}^{I} \Big(\sum_{m \in \phi(i)} R_n^m(i) - \sum_{m \in \varphi(i)} R_n^m(i) \Big)$$

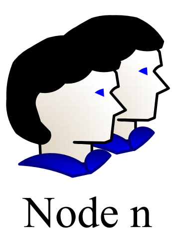
Maximize its own Expected rewards

Proposed Incentive Scheme

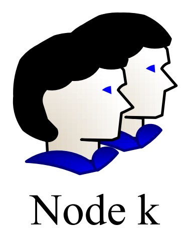
- 1. Exchange control information, including message list and EICP.



- 2. Generate message candidate list.



$$\tilde{L}_n = \hat{L}_k - (\hat{L}_n \cap \hat{L}_k)$$

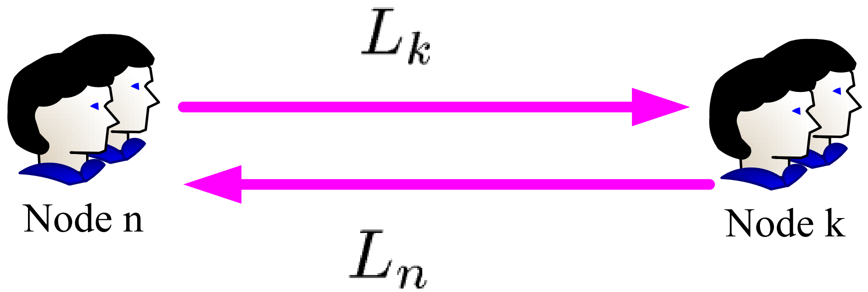


$$\tilde{L}_k = \hat{L}_n - (\hat{L}_k \cap \hat{L}_n)$$

- 3. Check matched messages and update credits.

Proposed Incentive Scheme

- 4. Exchange process is formulated as a two-person cooperative game, the final solution is determined by Nash Theorem.



- 5. Nodes n and k trade messages, pair by pair.

Nash Theorem

- The solution for two-person cooperative game, which allows players to reach a binding agreement and benefit both of them, is given by

$$(\hat{U}_n, \hat{U}_k) = arg \;\; max(U_n - D_n) \times (U_k - D_k)$$

-- *(D_n , D_k) is the status quo point;*

-- *(U_n , U_k) are the utility gains.*

-- *optimal solution yields an optimal set of messages that should be exchanged.*

Nash Solution

- A simple heuristic approach is adopted by considering one pair of message at a time.
  - Corresponding Nash product is calculated by assuming Messages n_m and k_p were exchanged .

Nash Product Table

L_K

L_n

	k_1	…	k_p
n_1	$U_n^{1,1} * U_k^{1,1}$	…	$U_n^{1,p} * U_k^{p,1}$
n_2	$U_n^{2,1} * U_k^{1,2}$	…	$U_n^{2,p} * U_k^{p,2}$
…	…	…	…
n_m	$U_n^{m,1} * U_k^{1,m}$	…	$U_n^{m,p} * U_k^{p,m}$

Simulations

- Our simulations are based on real mobility traces available at CRAWDAT.
  - Cambridge Haggle Project
  - UMass DieseNet Project
- Performance Metrics
  - Network-wide reception rate
  - Distribution of nodal performance
  - Average delivery delay
  - Message forwarding overhead
- We compare our work with "Direct" scheme, "SelfExchange" scheme, "CooperRdm" scheme and "Cooperative" scheme.

Simulation Results

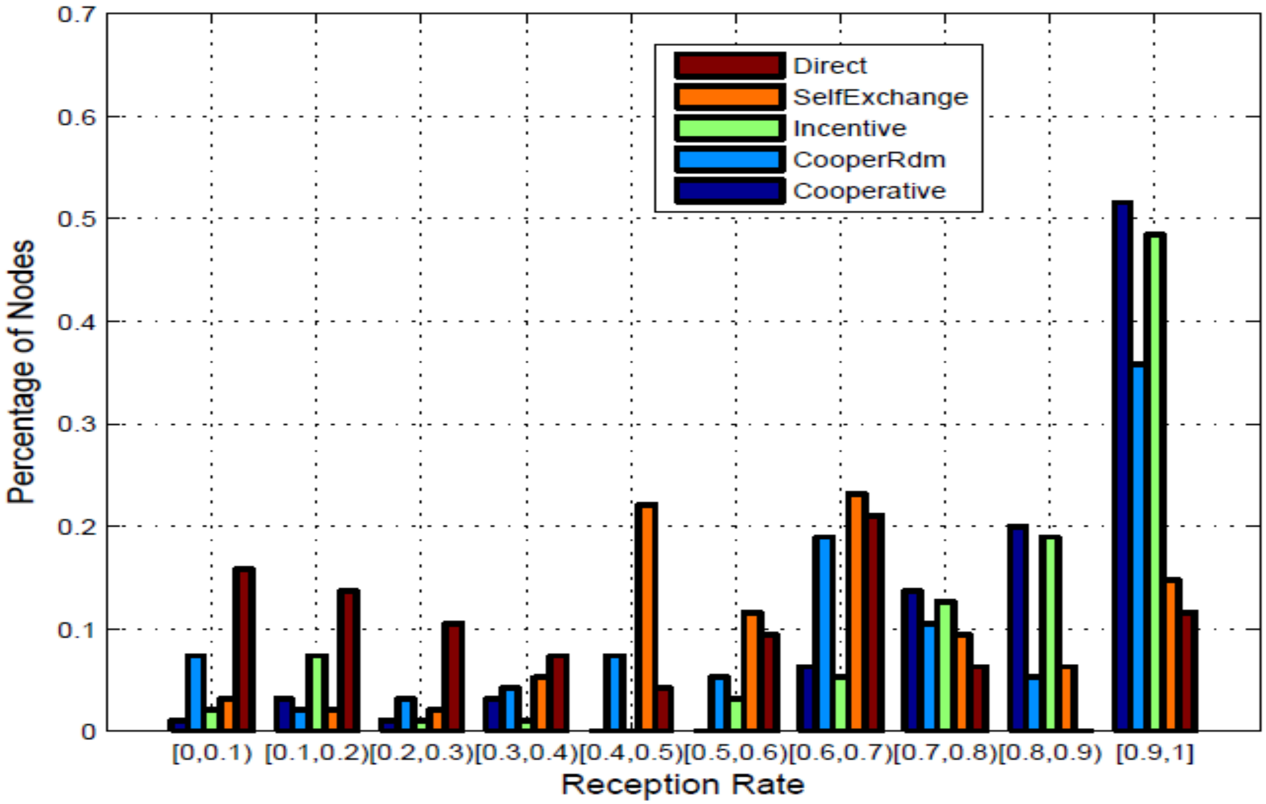
- Overall performance of all schemes based on the Haggle trace.

OVERALL PERFORMANCE COMPARISON BASED ON HAGGLE TRACE.

	Data Delivery Rate	Delay	Overhead
Direct	0.42	36109s (10.1h)	1
SelfExchange	0.58	22510s (6.25h)	1
CooperRdm	0.67	27653s (7.68h)	34
Incentive	0.82	10238s (2.84h)	2
Cooperative	0.86	8764s (2.43h)	10

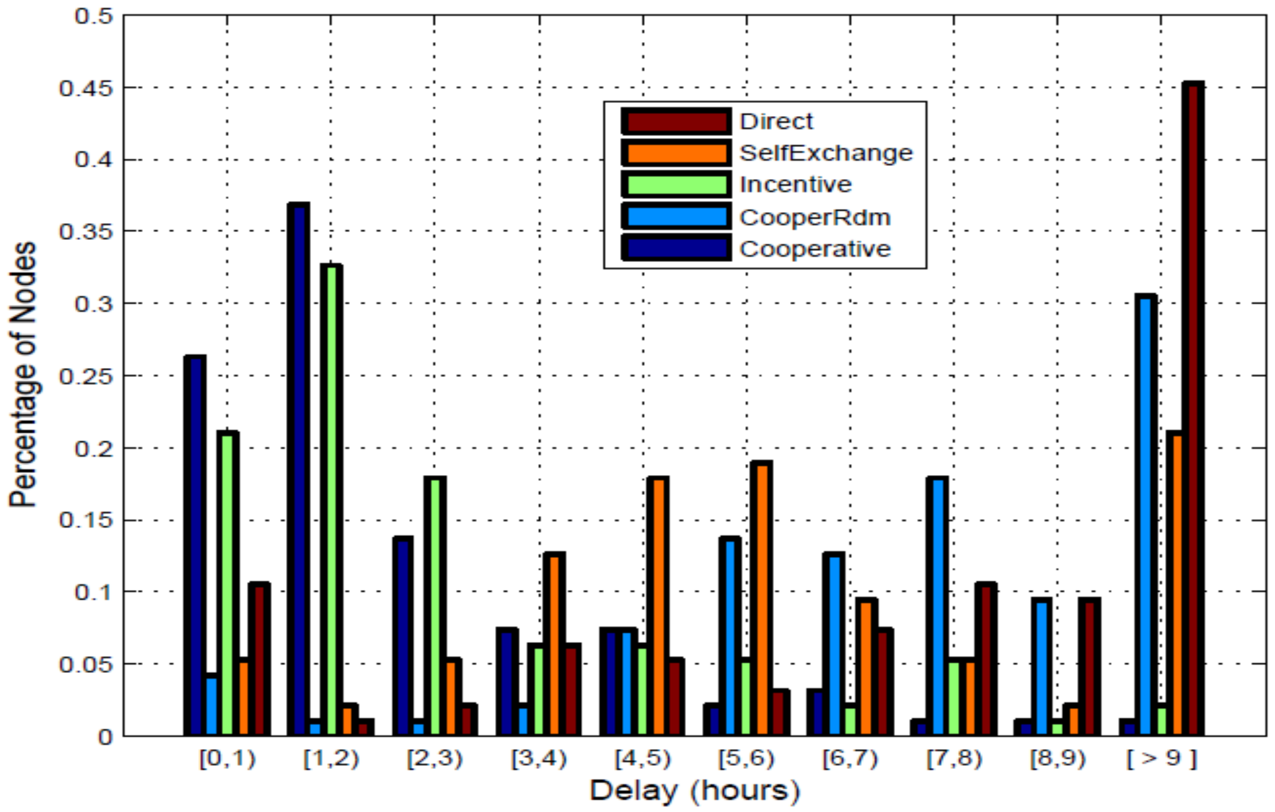
Simulation Results

- Distribution of nodal reception rate.
  - 48% of nodes under proposed scheme receive more than 90% of their interested messages.



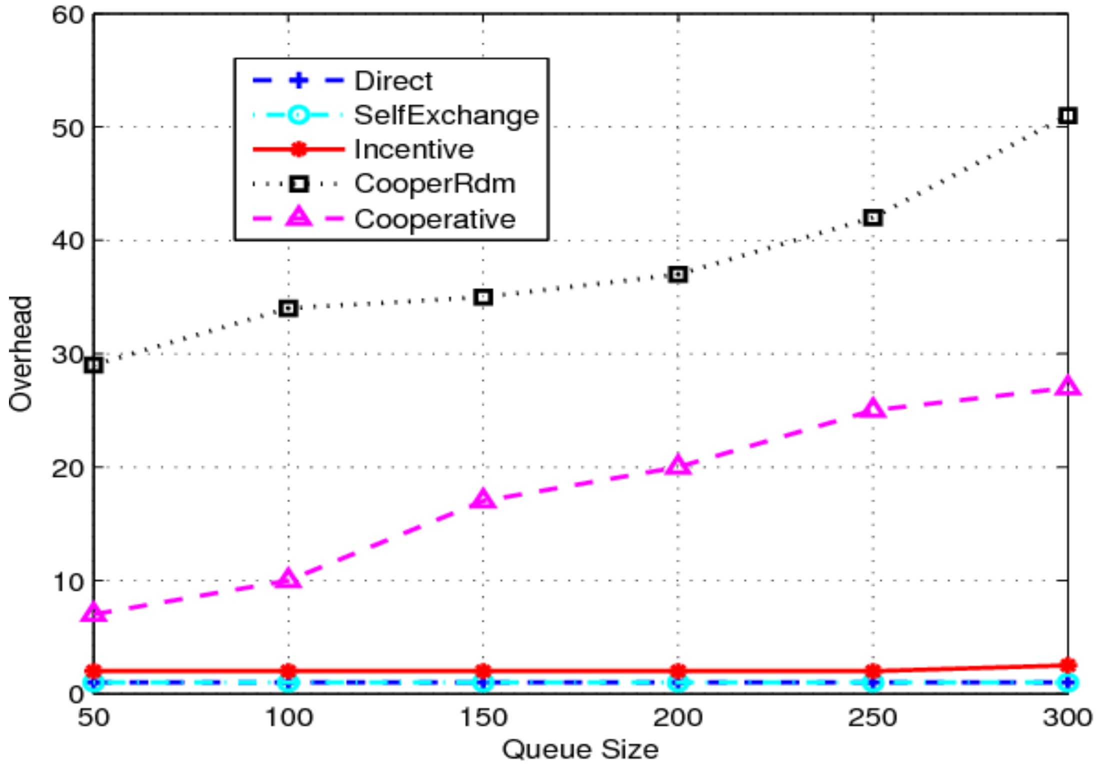
Simulation Results

- Distribution of nodal delay.
  - 56% of nodes receive message in less than 2 hours.



Simulation Results

- We evaluate all the schemes by varying
  - queue size
  - number of APs
  - data message generation rate, etc.



Conclusions

- A novel credit-based stimulation mechanism was proposed to address the data dissemination problem in selfish delay-tolerant mobile network.
- An effective way to track the value of a message that estimates potential rewards a node may gain.
- The final message exchange is formulated as a two-person cooperative game.
- The results show that our proposed incentive scheme is stable and has convincing performances.


Thank You