GIVE2GET: FORWARDING IN SOCIAL MOBILE WIRELESS NETWORKS OF SELFISH INDIVIDUALS

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ICDCS 2010

Outline

- Introduction
- Give2Get epidemic forwarding
- Give2Get delegation forwarding
- Experiment and result
- Conclusion

Introduction

- Topic: packet forwarding protocol in delay tolerant network
- Challenge: selfish individuals
  - Most protocols break down in this case
  - Selfish nodes drop every message except those destined to themselves
  - Selfish nodes cheat to others to avoid replicating others' messages.

Introduction

- Contribution: G2G epidemic forwarding protocol and delegation forwarding protocol
  - Cope with the social aspects of the network to tolerate selfish behavior
  - Propose protocols with high detection rate of misbehaviors
  - Indicate the protocols are Nash equilibrium

Give2Get Epidemic Forwarding

- Consist of three phases:
  - message generation, relay, test
- Message generation phase

$$m =< D, E_{PK_D}(S, msg\_id, body) >_s$$

  - S: source
  - D: destination
  - PK_D : public key of destination D

Give2Get Epidemic Forwarding

- Relay phase

$$A \xrightarrow{\langle \text{RELAY\_RQST}, H(m) \rangle_A} B \qquad (1)$$

$$A \xleftarrow{\langle \text{RELAY\_OK}, H(m) \rangle_B} B \qquad (2)$$

$$A \xrightarrow{\langle \text{RELAY}, H(m), E_k(m) \rangle_A} B \qquad (3)$$

$$A \xleftarrow{POR(m,A,B) \equiv \langle \text{POR}, H(m), A, B \rangle_B} B \qquad (4)$$

$$A \xrightarrow{\langle \text{KEY}, H(m), k \rangle_A} B \qquad (5)$$

Fig. 1. Protocol of the relay phase (in case node B does not have the message).

Give2Get Epidemic Forwarding

- Test phase
  - Execute when node B meets source node S again
  - Node B is asked to show two proofs of relay or to prove to still have the message in its memory.
  - If proof failed, node S broadcast a *proof of misbehavior* to the whole network.

Give2Get Epidemic Forwarding

- Test phase

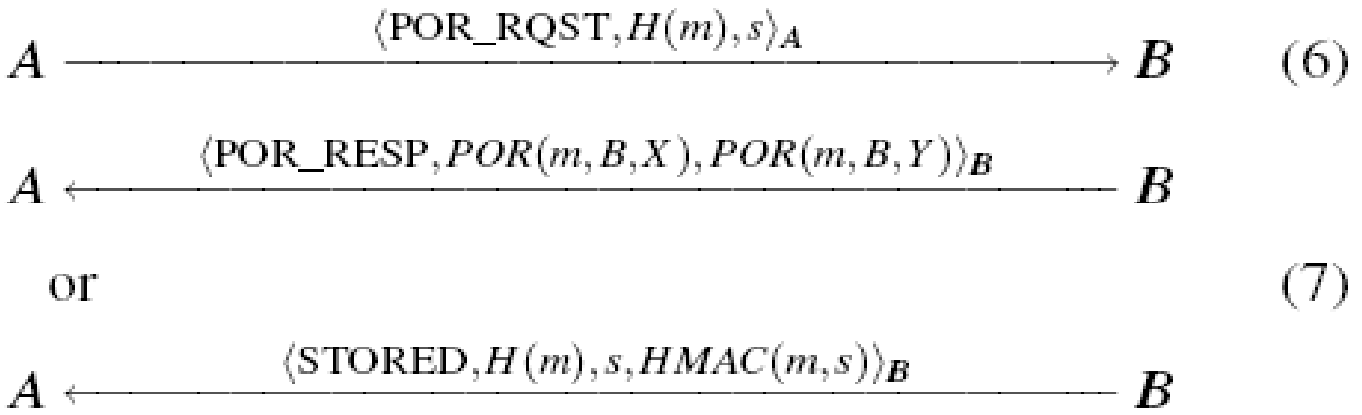


Fig. 2. Protocol of the test phase.

p.s.: HMAC: keyed hashing message authentication code

Give2Get Epidemic Forwarding

- Analysis on test phase
  - Time $\Delta 1$: after which B can stop looking for relays
  - Time $\Delta 2$: after which B can discard every information regarding the message
  - Properties of social network:

    If S and B meet, then it is likely that they will meet again in the near future
  - If setting $\Delta 2 = 2\Delta 1$, the detection rate is very high (more than 90%).

Give2Get Epidemic Forwarding

- Analysis on test phase
  - HMAC is heavy to compute, so that nodes prefer relay the messages to store them.

Give2Get Epidemic Forwarding

- G2G epidemic forwarding is a Nash Equilibrium
  - Possible strategies set Φ
  - Strategy chosen by i : s_i
  - Strategy profile $s = \{s_1, s_2, \ldots, s_n\}$
  - Payoff function: $f(s) = (f(s_1), \ldots, f(s_n))$
    - In terms of energy cost and memory cost in the system

Give2Get Epidemic Forwarding

- G2G epidemic forwarding is a Nash Equilibrium
  - Goal:
    - assume s=(π, …, π) while π is G2G epidemic forwarding,
    - s' is equal to s except in position i.
    - $s_i = \pi'$
    - to prove: $f_i(\pi') \leq f_i(\pi)$

Give2Get Epidemic Forwarding

- Lemma 1: Node rational node will follow all the steps of the relay phase truthfully
  - if A is source of message, he will take step 1 to deliver his own messages.
  - if A isn't the source of message, he will be tested by the source with a non-negligible probability.
    - HMAC consumes more energy than message relay
    - A choose to take step 1 instead store the message to achieve a higher payoff
  - Node A execute step 1 truthfully

Give2Get Epidemic Forwarding

- Lemma 1: Node rational node will follow all the steps of the relay phase truthfully
  - With the same argument, step 3 is executed truthfully
  - If node is receiver B, he has no idea about the destination of the message until step 5
  - To be able to receive the massage to him, node execute step 2 and step 4 truthfully.

Give2Get Epidemic Forwarding

- Lemma 1: Node rational node will follow all the steps of the relay phase truthfully
  - If sender A doesn't take step 5, node B will freeze the session with A.
  - A will not receive message from B
  - After many frozen session, the payoff of A drop to zero.
  - So, A execute step 5 truthfully.

Give2Get Epidemic Forwarding

- Lemma 2: A rational node will follow all the steps of the test phase truthfully.
  - Source node take the test phase, otherwise others will drop the message
  - Node B will take the risk of being removed from the system if he doesn't follow the steps of test phase.

Give2Get Delegation Forwarding

- Delegation forwarding
  - every node is associated with a forwarding quality
  - When a message is generated, it is associated with the forwarding quality of the sender.
  - node A checks whether the forwarding quality of B is higher than the forwarding quality of the message before forwarding.
  - If yes, node A creates a replica of the message, labels both messages with the forwarding quality of node B, and forwards one of the two replicas to B.

Give2Get Delegation Forwarding

- Delegation forwarding
  - reduce considerably the number of replicas, without reducing considerably success rate and delay
  - Not Nash equilibrium
  - A selfish node can easily send messages and receive messages without taking care of relaying any other message

Give2Get Delegation Forwarding

- The system is protected against to liars and cheaters
- Liars: claim that their quality is zero, and nobody can do much about this, these nodes would get their messages served without participating actively
- Cheaters: change the forwarding quality of the message to zero, in such a way to get rid of the message soon

Give2Get Delegation Forwarding

- Four phases consisted
  - Message generation
  - Relay
  - Test by the sender
  - Test by the destination

Give2Get Delegation Forwarding

- Relay phase

$$A \xrightarrow{\langle \text{FQ\_RQST}, H(m), D' \rangle_A} B \qquad (8)$$

$$A \xleftarrow{\langle \text{FQ\_RESP}, B, D', f_{BD} \rangle_B} B \qquad (9)$$

$$A \xrightarrow{\langle \text{RELAY}, H(m), f_m, E_k(m) \rangle_A} B \qquad (10)$$

$$A \xleftarrow{\langle \text{POR}, H(m), A, B, D', f_m, f_{BD} \rangle_B} B \qquad (11)$$

$$A \xrightarrow{\langle \text{KEY}, H(m), k \rangle_A} B \qquad (12)$$

Fig. 6. G2G Delegation Forwarding: Protocol of the relay phase.

Give2Get Delegation Forwarding

- Relay phase
  - When the destination of m is different from B, D_0 is the actual destination D;
  - When the destination of m is B, D_0 is chosen as a random node different from B.
  - Ensure that B don't know whether it is the destination of the message or not before taking the message and giving the proof of relay

Give2Get Delegation Forwarding

- Test by destination
  - The sender stores the signed message

$$< FQ\_RESP, B, D, f_{BD} >_B$$

for the nodes B that failed to be good relays for the message, which is $f_{BD} < f_m$

  - The last two signed qualities of such failed relays are embedded into the message towards D

Give2Get Delegation Forwarding

- Test by destination
  - If the destination D receives the message, it will be able to check if f_{BD} is correct or not
  - If $f_{BD} = f_{DB}$, correct
  - Else, node B is a liar. D will also broadcast the misbehavior of node B to the network

Give2Get Delegation Forwarding

- Test by destination
  - f_{BD} is the quality computed in the last completed timeframe.
  - Every node keeps three versions of the forwarding quality: the current and the two forwarding qualities computed in the previous two completed timeframes.
  - In that way, B and D have a consistent notion of forwarding quality.

Give2Get Delegation Forwarding

- Test by sender
  - Two proofs of relay: $< POR, H(m), A, B, D, f_m^1, f_{BD} >_B$

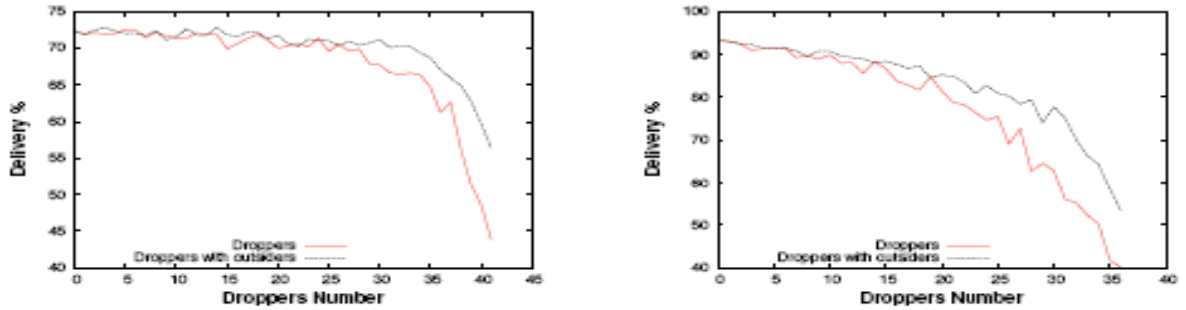
    $< POR, H(m), A, C, D, f_m^2, f_{CD} >_C$
  - check whether:

$$f_{AD} = f_m^1 < f_{BD} = f_m^2 f_{CD}$$

Experiment and result

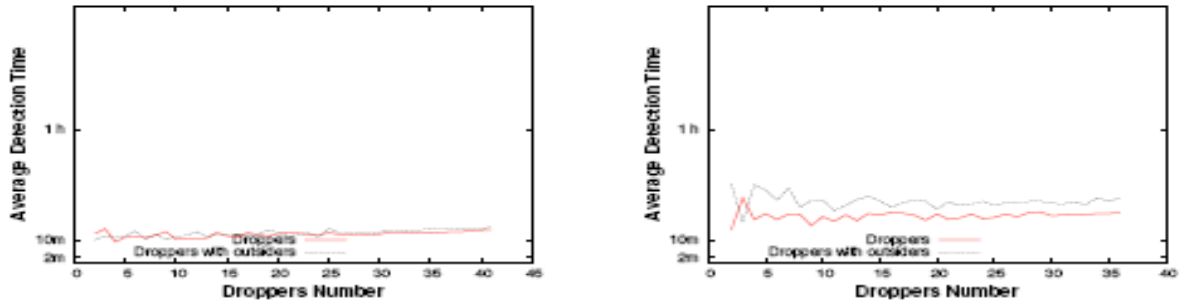
- The data set:
  - Cambridge 06: number of mobile devices used is 36. This experiment covers 11 days.
  - Infocom 05: The number of devices is 41. This experiment covers approximately 3 days.

Experiment result-G2G epidemic forwarding



(a) Infocom05 (b) Cambridge06

Fig. 3. Effect of message droppers on Epidemic Forwarding



(a) Infocom05 (b) Cambridge06

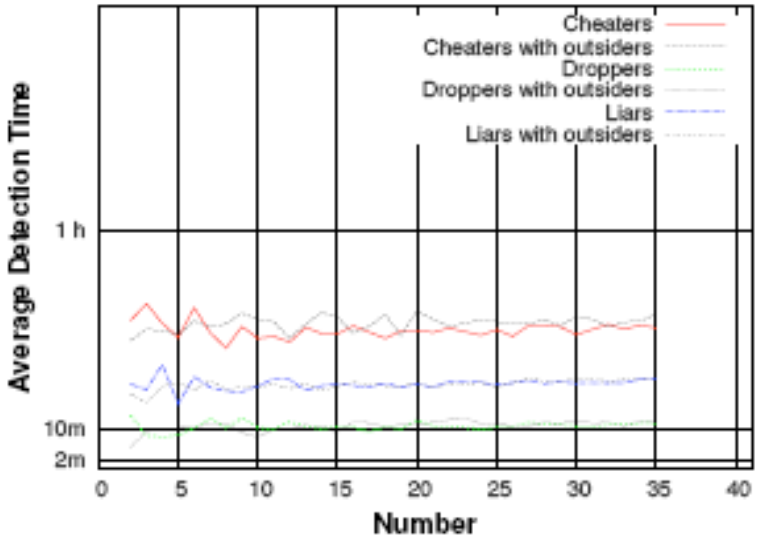
Fig. 4. Dependence of droppers detection time from the number of droppers in G2G Epidemic Forwarding. Detection time is considered after the expiring of TTL value Δ_1 of message.

Experiment result-G2G delegation forwarding

- Performance of G2G delegation forwarding on the real traces

	Infocom 05		Cambridge 06	
	Detection Rate	Avg detection time (minutes)	Detection Rate	Avg detection time (minutes)
Droppers	88%	12	86%	21
Liars	67%	26	65%	52
Cheaters	83%	35	84%	64
Droppers with outsiders	87%	15	84%	23
Liars with outsiders	64%	28	62%	54
Cheaters with outsiders	83%	37	81%	68

Experiment result-G2G delegation forwarding



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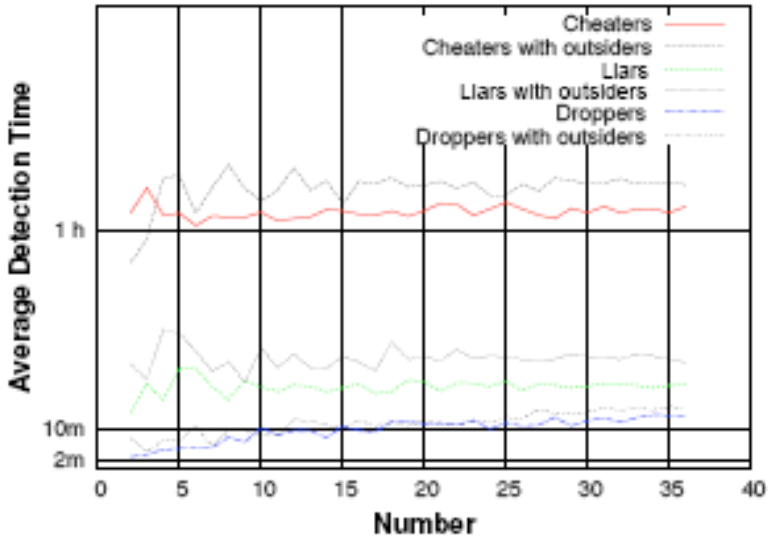

(b) Cambridge06

Conclusion

- Present an efficient approach to prove the advantage of your design.
- Provide an example on the design focusing on the real behaviors of selfish users