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Two-Sided Statistical Disclosure Attack

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Talk Outline

- Disclosure Attacks and Anonymity
- Modelling replies
- The Two-Sided Statistical Disclosure Attack
- Evaluation
- Discussion and Conclusions

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Disclosure Attacks

- Anonymous communications: hide communication partners
- Attacker objective: reveal Alice's contacts
- Threshold mix
- Passive attacker
  - Observes the network for many rounds
  - Exploit persistent patterns

Disclosure Attacks: Previous work

- Solving NP-Complete problem [Kesdogan03]
- Simplified model
  - Sensitive to changes

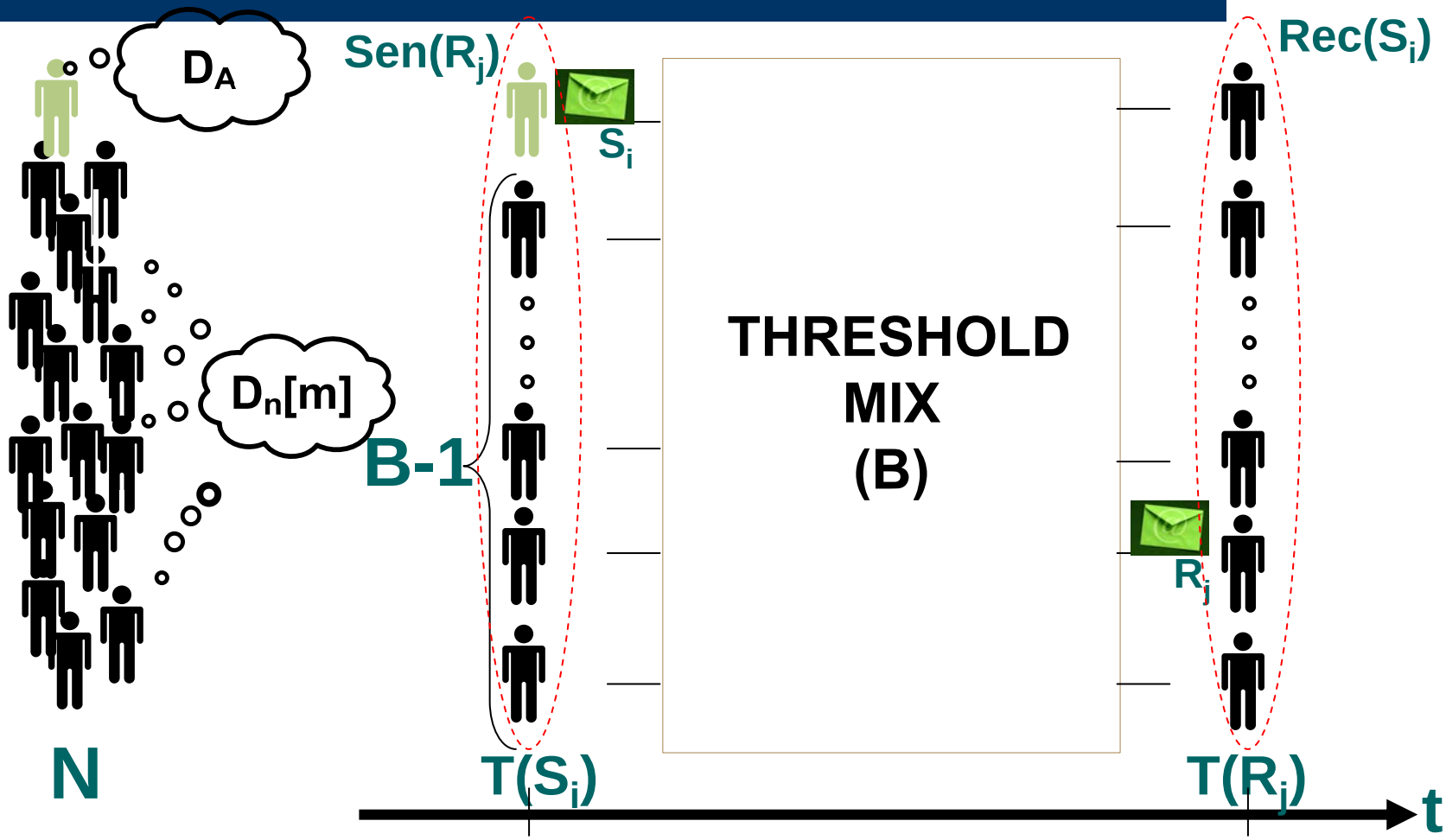
- Statistical Disclosure Attacks [Danezis03]
  - Reduce complexity

- Two-sided Statistical Disclosure Attacks
  - Include replies

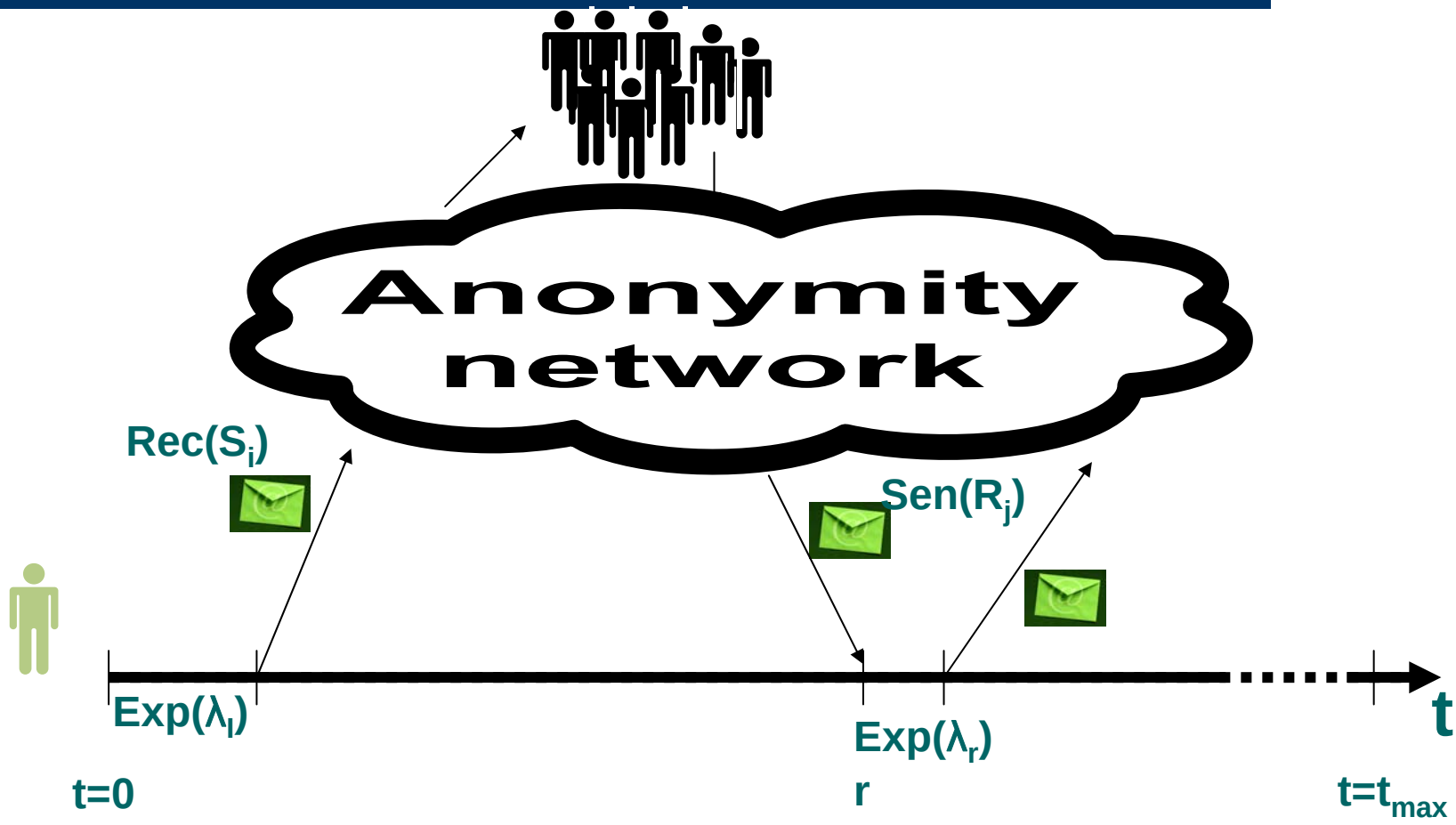
Introducing replies in the model

- Indistinguishable from normal messages
- Parameters:
  - Choice of partners
    - Distribution of contacts
  - Start a new discussion
    - Poisson process
  - Replying?
    - Fixed known probability
  - Time to reply
    - Exponential
- Independent

Introducing replies: The general formal model



Introducing replies: The replies in the formal model



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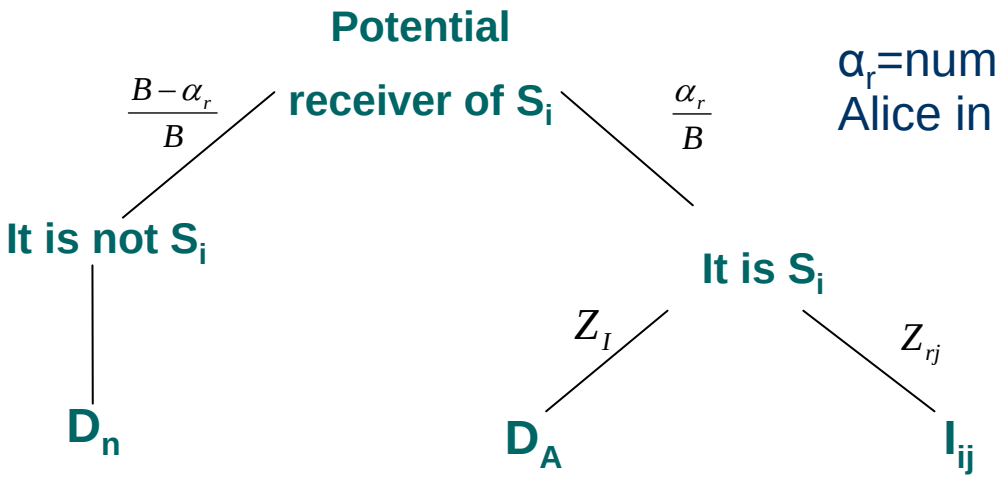
The Two-Sided Statistical Disclosure Attack

- Uses
  - Rounds with Alice sending/receiving
  - Time sending/reception
- Objective
  - Estimate D_A
  - Infer receiver per round
    - Contribution from Alice (D_A)
    - Contributions from other senders (D_n)
    - Potential receivers of replies

The Two-Sided Statistical Disclosure Attack



α_r=number of messages sent by Alice in round r

$$I_{ij} = \frac{\mathrm{Re}\,c(S_i)\cdot Sen(R_j)}{\left\|\mathrm{Re}\,c(S_i)\cdot Sen(R_j)\right\|_1}$$

$$\mathrm{Re}\,c(S_i) \sim \frac{\alpha_r}{B}\frac{Z_I D_A + \sum_j Z_{rj} I_{ij}}{Z_I + Z_r} + \frac{B-\alpha_r}{B} D_n$$

The Two-Sided Statistical Disclosure Attack

$$\mathrm{Re}\,c(S_i) \sim \frac{\alpha_r}{B} \frac{Z_I D_A + \sum_j Z_{rj} I_{ij}}{Z_I + Z_r} + \frac{B - \alpha_r}{B} D_n$$

$$D_A \sim \frac{(B \cdot \mathrm{Re}\,c(S_i) - (B - \alpha_r) D_n)(Z_I + Z_r)}{\alpha_r Z_I} \equiv C_i \Rightarrow \hat{D}_A \approx \frac{1}{K_s} \sum_{\forall i} C_i$$

$$\mathrm{Re}\,c(S_i)' \sim \left(\frac{\alpha_r}{B} \frac{Z_I \hat{D}_A + \sum_j Z_{rj} I_{ij}}{Z_I + Z_r} + \frac{B - \alpha_r}{B} D_n \right) \cdot \mathrm{Re}\,c(S_i)$$

From traffic in rounds where Alice is not present

[Mathewson and Dingledine 04]

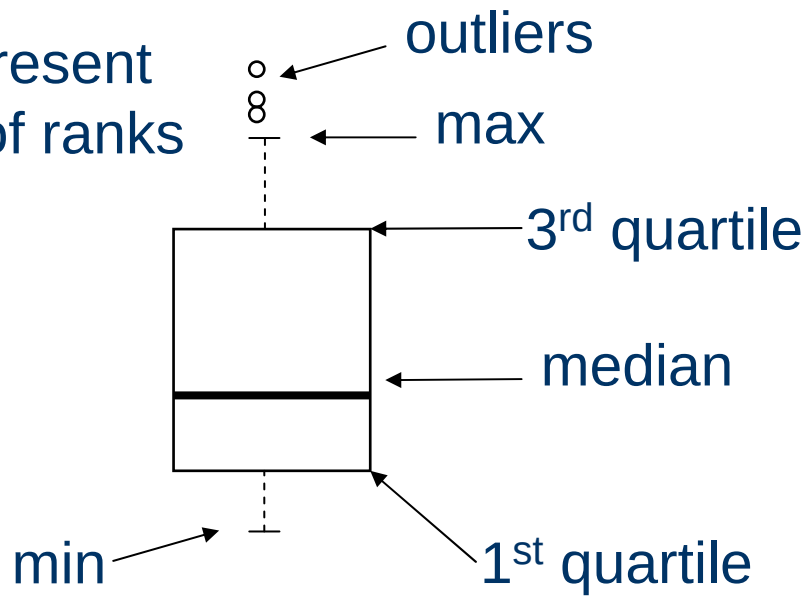
Evaluation: Method

- We compare with SDA
- **Rank**: number of receivers in Rec(S_i)' with at least the same probability as the real receiver

Rec(S_i)'
0.1
0.2
0.05
0.125
0.07
0.155
0.1
0.2

Rank = 4

- Box plot represent distribution of ranks

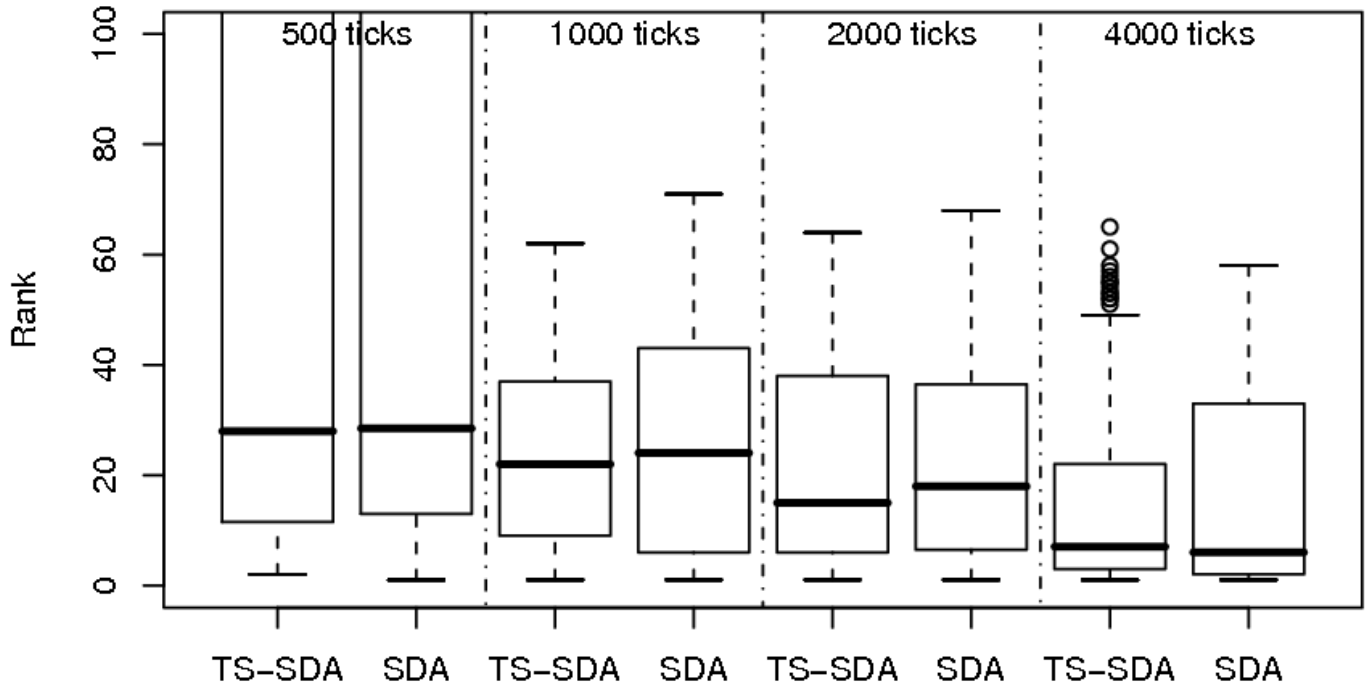


Evaluation: Standard parameters

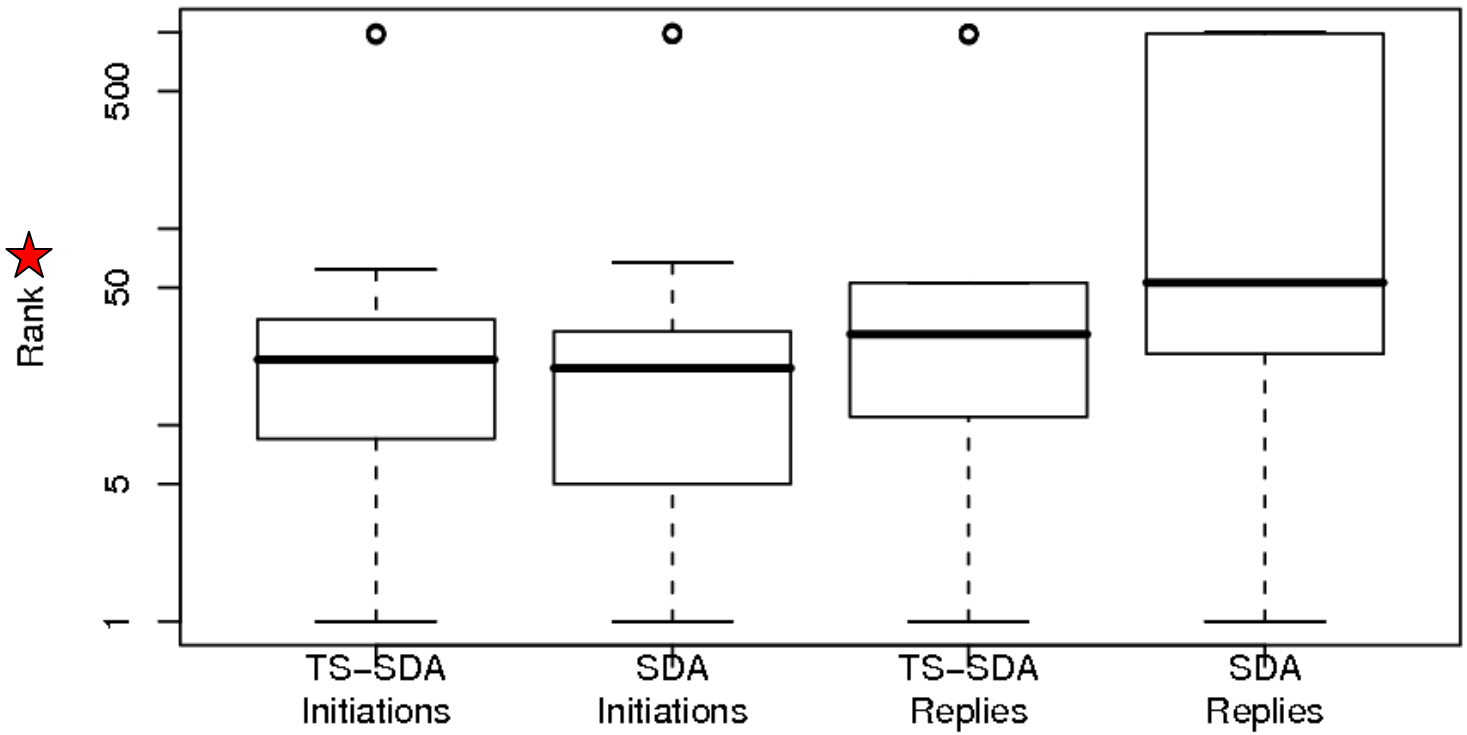
Name	Value	Description
N	1000	Number participants
k	20	Alice's contacts
B	100	Mix threshold
t_{max}	4000	Observation time
λ_l	1/10	Initiation rate
r	0.5	Reply probability
λ_r	1/2	Reply delay rate

- Alice sends with uniform probability to her contacts
- The rest send with uniform probability to all the users
- Only Alice replies to messages

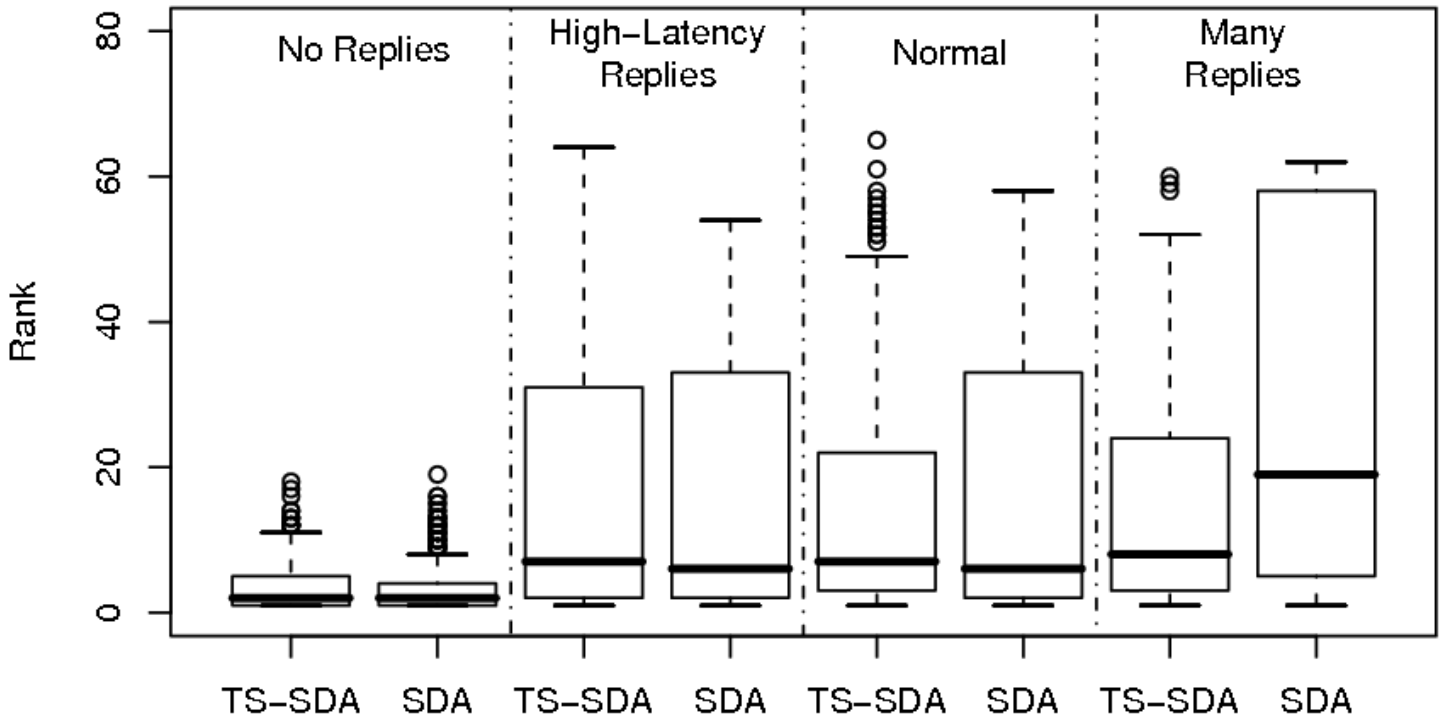
Evaluation: Observation time



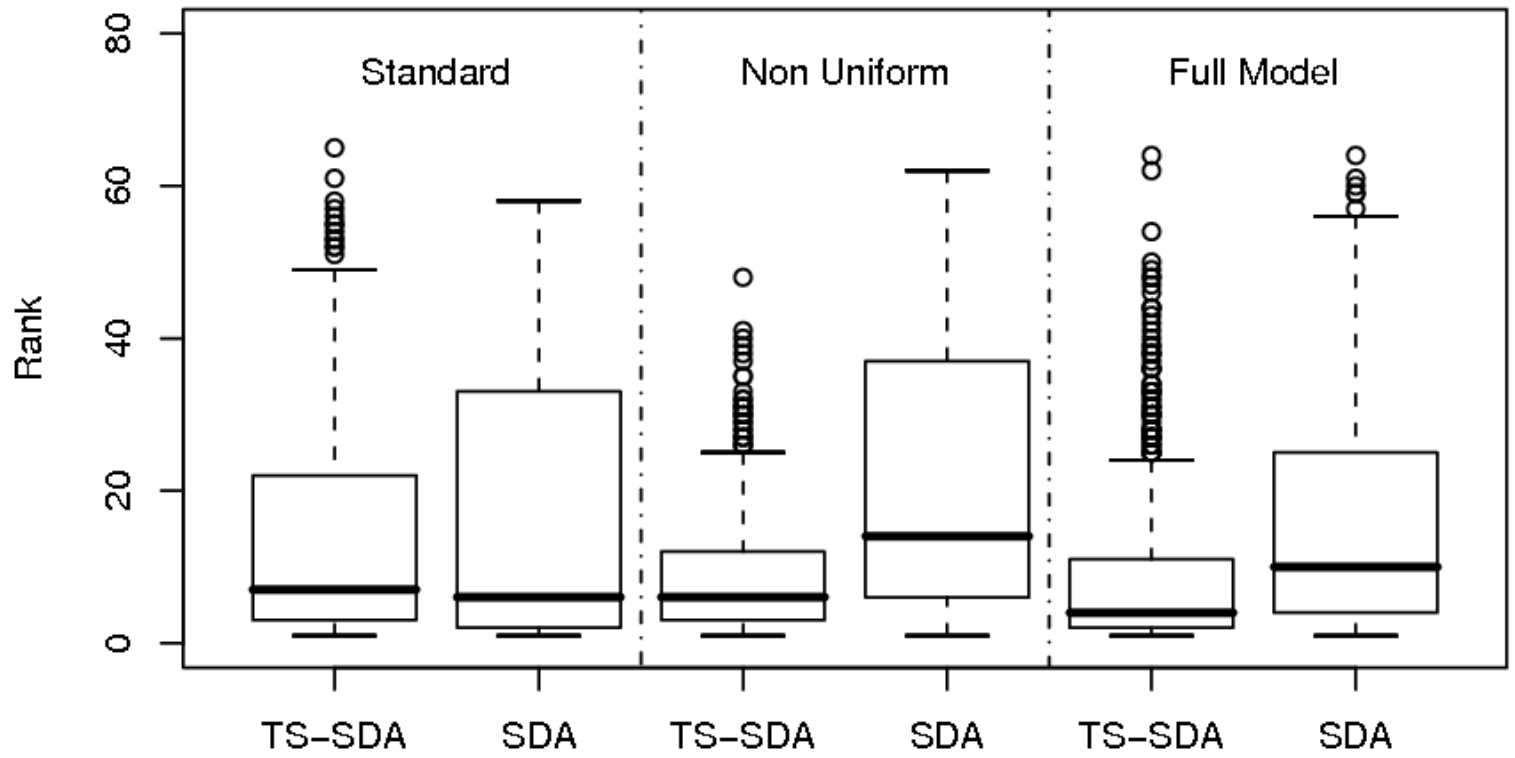
Evaluation: Initiations vs. replies



Evaluation: Replies rate



Evaluation: Background traffic



Discussion

- The model is not realistic
  - Poisson process for initiating discussions
  - Parameters independent
  - Replying uniformly
  - Only one reply per message
  - Other anonymity systems

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Conclusion

- First attack and model including anonymous replies
- The attack is fast
  - Only operations on vectors
  - Linear with the number of messages $O(K_s)$
- Evaluation in different conditions
- The timing of replies is crucial
- Indistinguishable replies increase anonymity
- Unrealistic model: lack of data

Thank you

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