

ShareTrace: Proactive Contact Tracing with Asynchronous Message Passing

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Introduction: Types of Contact Tracing

- ▶ Digital contact tracing (DCT)
- ▶ Proximity tracing
- ▶ Decentralized DCT
 - ▶ Broadcast model
 - ▶ Message-oriented model

Introduction: Limitations of Other Approaches

- ▶ No DCT approach exists that incorporates both non-diagnostic information and indirect contacts to estimate infection risk.
- ▶ Account for indirect contact can substantially improve the efficacy of DCT [10].
- ▶ Cherini et al. [4] propose exchanging pseudonyms of indirect contacts, but restrict themselves to diagnostic testing.
- ▶ Gupta et al. [6] incorporate non-diagnostic information, but do not account for indirect contact.

Introduction: ShareTrace

- ▶ Accounts for both non-diagnostic information and indirect contact to estimate infection risk.
- ▶ First proposed by Ayday, Yoo, and Halimi [1] and Ayday et al. [2] as part of a collaboration with Dataswyft.
- ▶ Ayday, Yoo, and Halimi [1]

Proposed Design

Experiment 1: Accuracy I

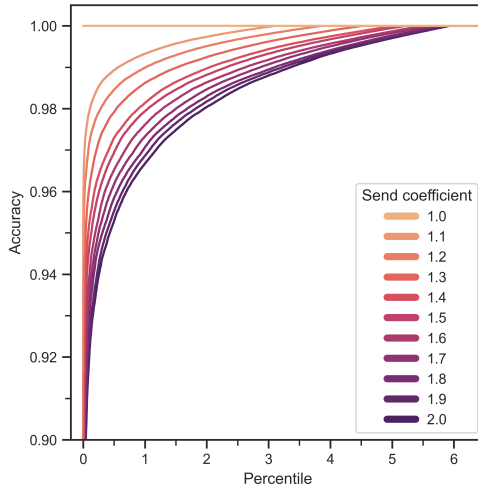


Figure: Cumulative accuracy distributions.

Experiment 1: Accuracy II

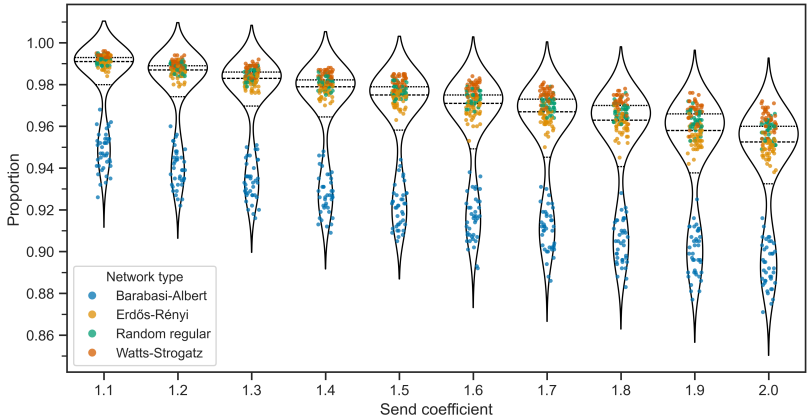


Figure: Send coefficient optimality distributions. The dashed line inside each violin marks the median. The upper and lower dotted lines inside each violin mark the upper and lower quartiles, respectively.

Experiment 1: Efficiency I

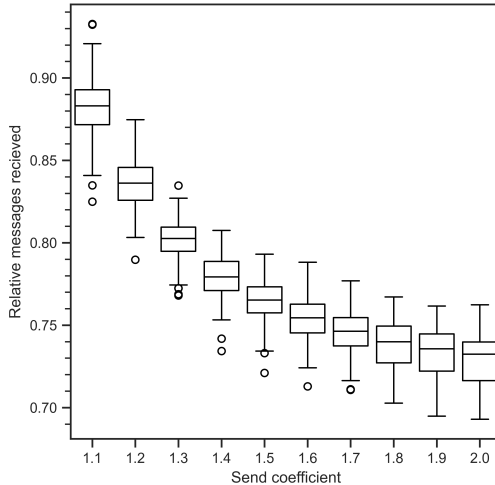


Figure: Message-passing efficiency. The send coefficient $\gamma = 1$ was used as a baseline for message-passing efficiency since it was found to be the maximum send coefficient that achieves perfect accuracy.

Experiment 1: Efficiency II

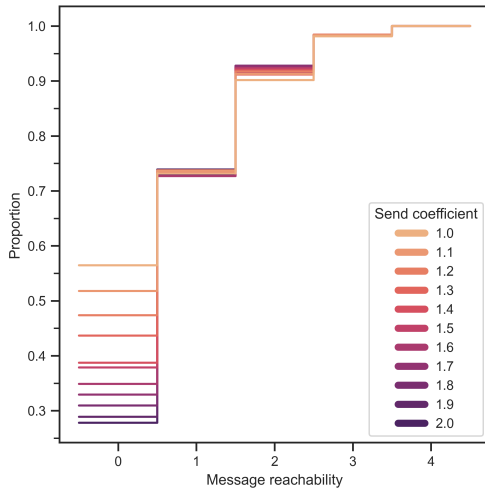


Figure: Message reachability cumulative distributions.

Experiment 1: Exploration I

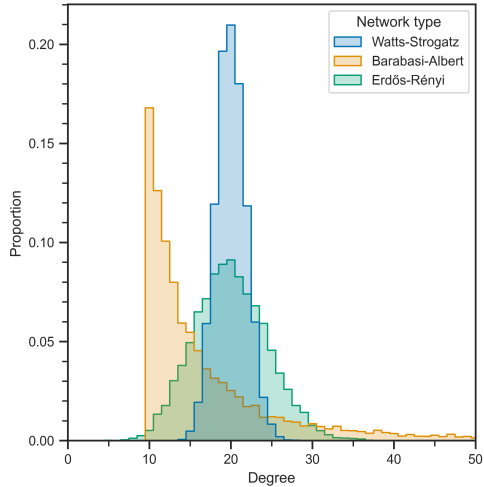


Figure: Contact network degree distributions. All vertices in random regular contact networks had a degree of 20, so the distribution was omitted to provide more visual space for the distributions of other contact networks.

Experiment 1: Exploration II

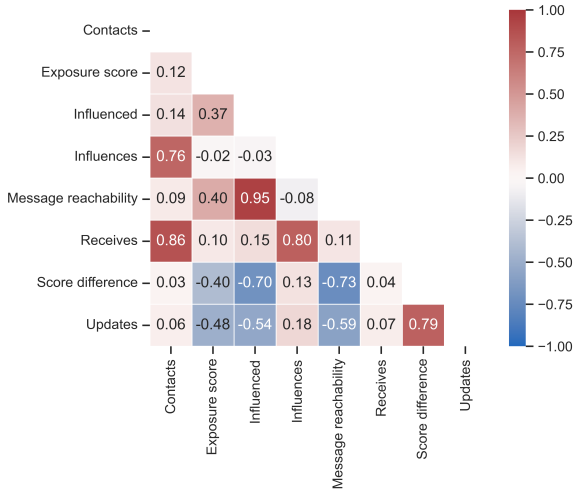


Figure: Correlation matrix of dataset attributes. Each cell is the Spearman rank partial correlation coefficient [15], controlling for the effect of the send coefficient. All coefficients are significant ($p < 0.01$), adjusting for multiple comparisons via the Holm–Bonferroni method [7].

Experiment 2: Benchmarking Hypothesis Testing

Experiment 3: Benchmarking I

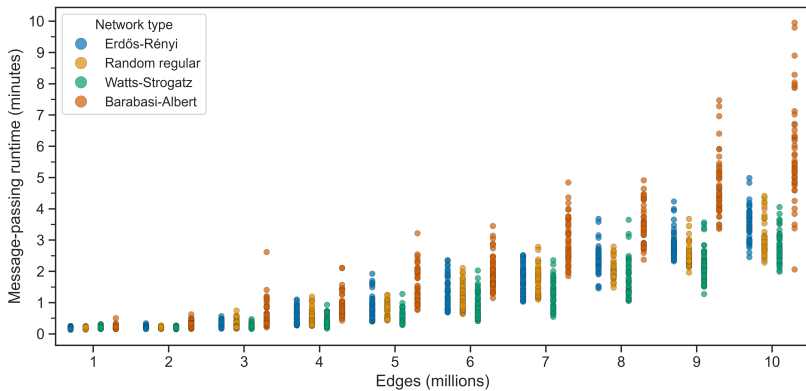


Figure: Message-passing runtimes.

Experiment 3: Benchmarking II

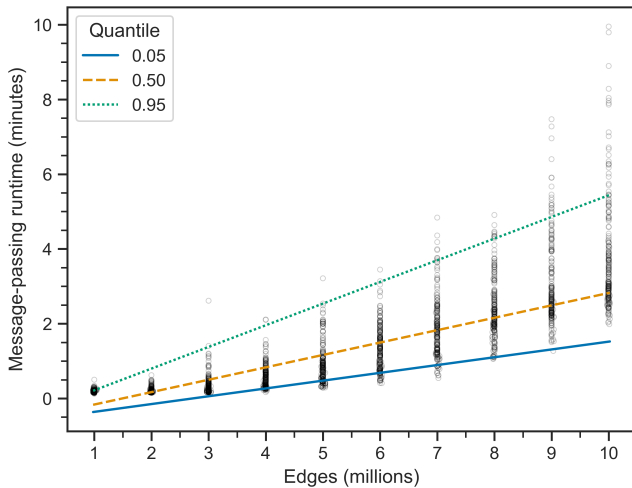


Figure: Message-passing runtimes with regression lines.

Conclusion: Future Work

- ▶ Incorporate differential privacy techniques that are designed for DCT applications that utilize risk scores [12].
- ▶ Formally define the security and privacy characteristics of ShareTrace, using the framework proposed by Kuhn, Beck, and Strufe [9] to characterize the latter.
- ▶ Conduct a simulation-based analysis of asynchronous risk propagation with COVI-AgentSim [5].
- ▶ Explore the utility and feasibility of integrating decentralized technologies [3, 8, 14, 17, 18] and self-sovereign identity [11, 13] into the system design.

Prior Designs and Implementations

- ▶ “Thinking like a vertex” with Apache Giraph
- ▶ Factor subgraph actors
- ▶ Driver-monitor-worker framework
- ▶ Projected subgraph actors [16]
- ▶ Contact search

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