Topology Control for Time-Evolving and Predictable Delay-Tolerant Networks

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Outline

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Introduction

• Predictable DTNs
  – Clear socio-temporal patterns, e.g. public buses [13], satellites [19], or mobile social networks consisting of students, 93% potential predictability [20]

• Problem
  – How to smartly control the dynamic topology for such time-evolving and predictable DTNs

• Contributions
Fig. 1. **A time-evolving DTN:** (a) a snapshot of the network, (b) time-evolving topologies of the DTN (a sequence of snapshots).
Model & The Problem

- **Space-Time Graph**

![Graphs](https://via.placeholder.com/150)

Fig. 2. **Different graph models for the time-evolving network shown in Figure 1:** (a) a sequence of snapshots of the network at each time slot, denoted by \( \{G^t\} \); (b) and (c) its corresponding aggregated graph model.
Fig. 3. Space-time graph model from the same time-evolving network in Figure 2: (a) the corresponding space-time graph $G$; (b) a space-time path (in blue) from the source $v_2$ to the destination $v_5$. 
• New Topology Control Problem

Fig. 4. Topology control on time-evolving network (the one shown in Figure 1): (a) a new connected subgraph $\mathcal{H}$ of $\mathcal{G}$ (green links are removed links from Figure 3(a)); (b) its corresponding sequence of static graph with less links than the one of Figure 2(a).
• NP-hardness Proof (Directed Steiner Tree, DST Problem)

Fig. 5. Reduction from (a) the directed Steiner tree problem to (b) our TC problem on space-time graphs. Here the blue structures are the corresponding solutions in DST and TC.
Topology Control for Directed DTNs

• Shortest Path Tree method (SPT)
  – Time complexity:

\[ O(Tn^3 + Tn^2 \log(Tn)) \]
• Greedy Algorithm based on Least Cost Path (GrdLCP)
  – Time complexity: $O(Tn^5 + Tn^4 \log(Tn))$
• Greedy Algorithm based on Least Density Bunch (GrdLDB)
  – Inspired by the Directed Generalized Steiner Network (DGSN)
  – Time complexity: \( O(T^2n^6 \log n) \)
  – Approximation ratio: \( O(n^{4/3} \log^{1/3} n) \)
Topology Control for Undirected DTNs

- Converting method one – Double Cost
- Converting method two – New Graph
Simulations

Fig. 10. Topologies generated over the same random network: green links are removed links from the original graph $\mathcal{G}$, while black links are the ones kept by each algorithm. (a-c): $p = 0.1$, (d-f): $p = 0.8$. 
Fig. 12. Simulation results on networks from Cambridge Haggle [34] tracing data. Results are averages over 13 small networks.
Thanks!