Polystyrene: The Decentralized Data Shape that Never Dies

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Focus

- Epidemic Topology Construction algorithms

- Decentralized, fast, scalable
- Fundamental building block to higher-level services (DHT, Multicast, Pub-Sub, Recommendations)

Taken from [JMB09]
Problem: Catastrophic Failure

- The topology **heals**
- But the overall **shape** is **lost**

**How to recreate whole shape from surviving nodes?**
Outline

- Background:
  Decentralized Topology Construction
- Polystyrene:
  Architecture and Protocol
- Evaluation
- Outlook
Decentralized Topology Const.

- Each node: some data
- Find k "closest" nodes in system
  ➔ Decentralized approach, asynchronous rounds
Main idea: greedy neighbourhood optimization

1. exchange of neighbors lists
2. neighborhood optimization
Polystyrene’s Architecture

Polystyrene

Topology Construction
(T-Man, Vicinity, Gossple)

Peer Sampling Service
(RPS, Cyclon, SCAMP)

Node position

Neighbours
Polystyrene Protocol

1' backup (incoming)

3 projection

Node position

Topology Construction

2 recovery

1 backup (outgoing)

migration

3' Neighbours
The Migration Process

\[ p.guests_t \]

\[ p.pos_t \]

\[ q.guests_t \]

\[ q.pos_t \]
The Migration Process

Bi-clustering of guest points

Heuristics: diameter
The Migration Process

- Bi-clustering of guest points
  - Heuristics: diameter
The Migration Process

- Bi-clustering of guest points
  - Heuristics: diameter + minimum move
Evaluation

- Shape: 3D torus (replication $K = 4$)
- Round 20: 50% correlated node crashes
- Round 100: 50% node reinjection (repair)

Polystyrene recreates shape with surviving nodes
Evaluation: Node Reinjection

Polystyrene, $r = 125$

T-Man, $r = 125$

Polystyrene recreates uniform shape after repair
proximity = \mathbb{E}_{n_i \in \text{nodes}} \left( \mathbb{E}_{n_j \in n_i.\text{neighbors}} d(n_i.\text{pos}, n_j.\text{pos}) \right)

Polystyrene maintains good neighborhoods
Eval: Quality of Shape

\[ \text{homogeneity} = \mathbb{E}_{x \in \text{data-points}} \left( \min_{n \in \hat{\text{guests}}^{-1}(x)} \{ d(x, n.\text{pos}) \} \right) \]

And the torus gets restored!
Eval: Overheads

Message + Memory

Reasonable Cost
Eval: Scalability (1)

- Time (rounds) until homogeneity less than

\[ H_{\mathcal{A}}^{|N|} = \frac{1}{2} \sqrt{\frac{\mathcal{A}}{|N|}} \]

Logarithmic convergence!
Eval: Scalability (2)

- Strong influence of splitting mechanism

Diagram:
- Reshaping time (# rounds) vs. Size of network (# nodes)
- Split_Basic
- Split_Advanced (MD+PD)
- Split_MD
Outlook

- Behaviour in **different shapes**
  - Ring, grid, logical torus

- **Proof** of logarithmic convergence

- **Concrete application** on top of polystyrene
  - DHT, recommendation

- Larger picture
  - Self-organising data primitives for geo-systems