Analyzing Failures as Noise

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The Question:

Can changes in topology be analyzed as noise input?

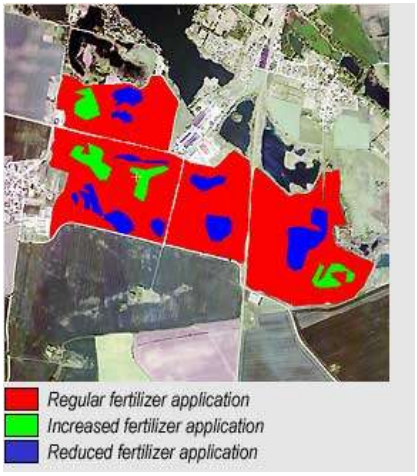
Test Algorithm: Persistent Node Hierarchy

- Goal: Hierarchical Addressing & Routing
- Noise Metric: Δ Conductance
- Correctness Metric: Routing Stretch

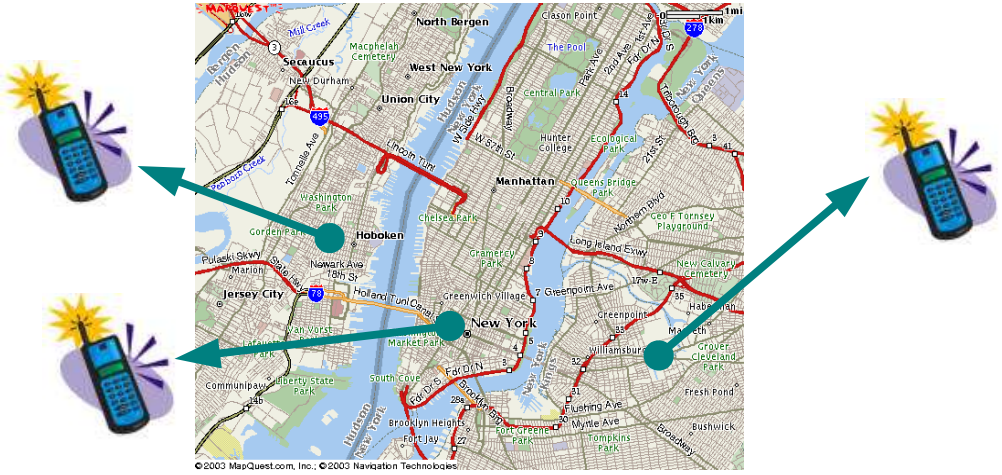
Big Self-Organizing Networks

Example Applications:

Traffic Monitoring and Control



Agricultural Management



Peer-To-Peer Cellular Network

Big Self-Organizing Networks

- $> 10^7$ nodes
  - Low mobility
  - Direct, centralized administration impossible
  - Continuous failure and replacement
  - Correlated large-scale failures

Conventional Failure Analysis

- Maximum *F* stopping/byzantine failures

  Failure of up to *F* nodes still results in correct final outcome

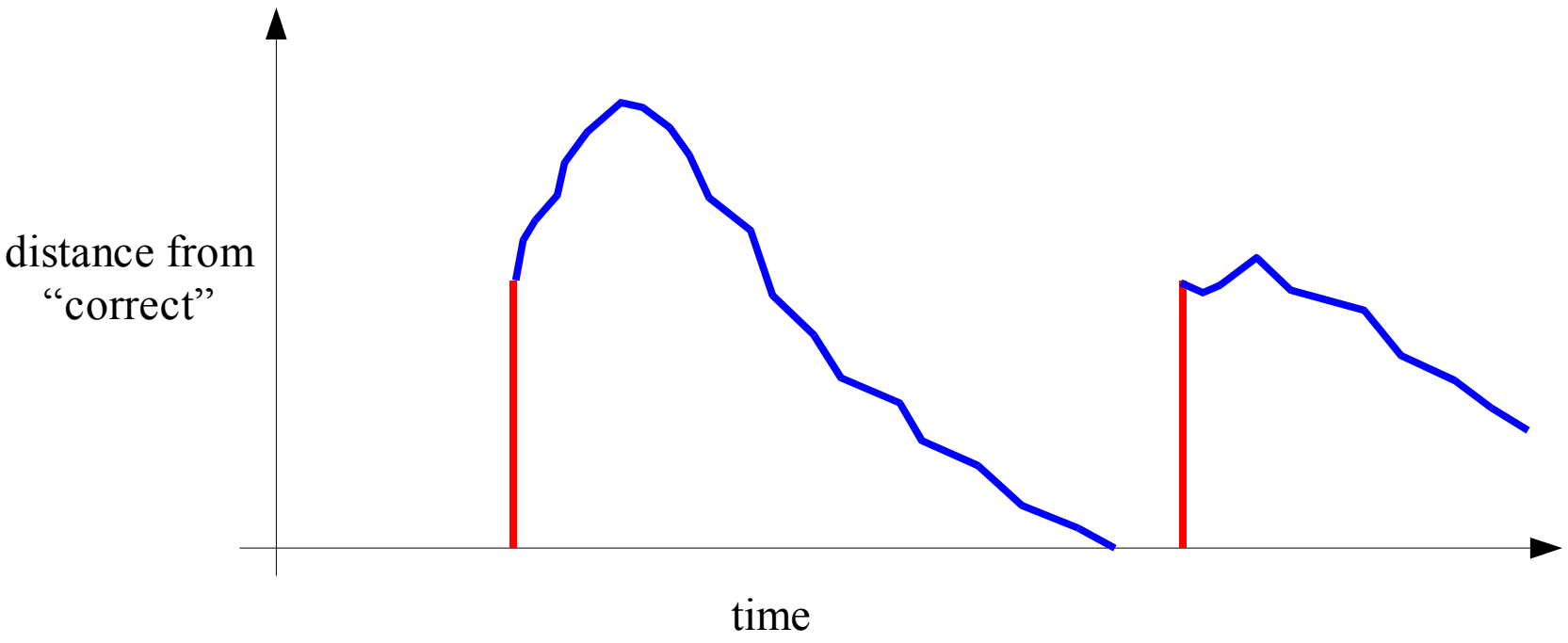
- Bounded Half-Life Criteria [Liben-Nowell et al]

  Correct operation on *N* nodes while adversary chooses up to *2N* joins or *N/2* failures in time *t*

- Self-Stabilization

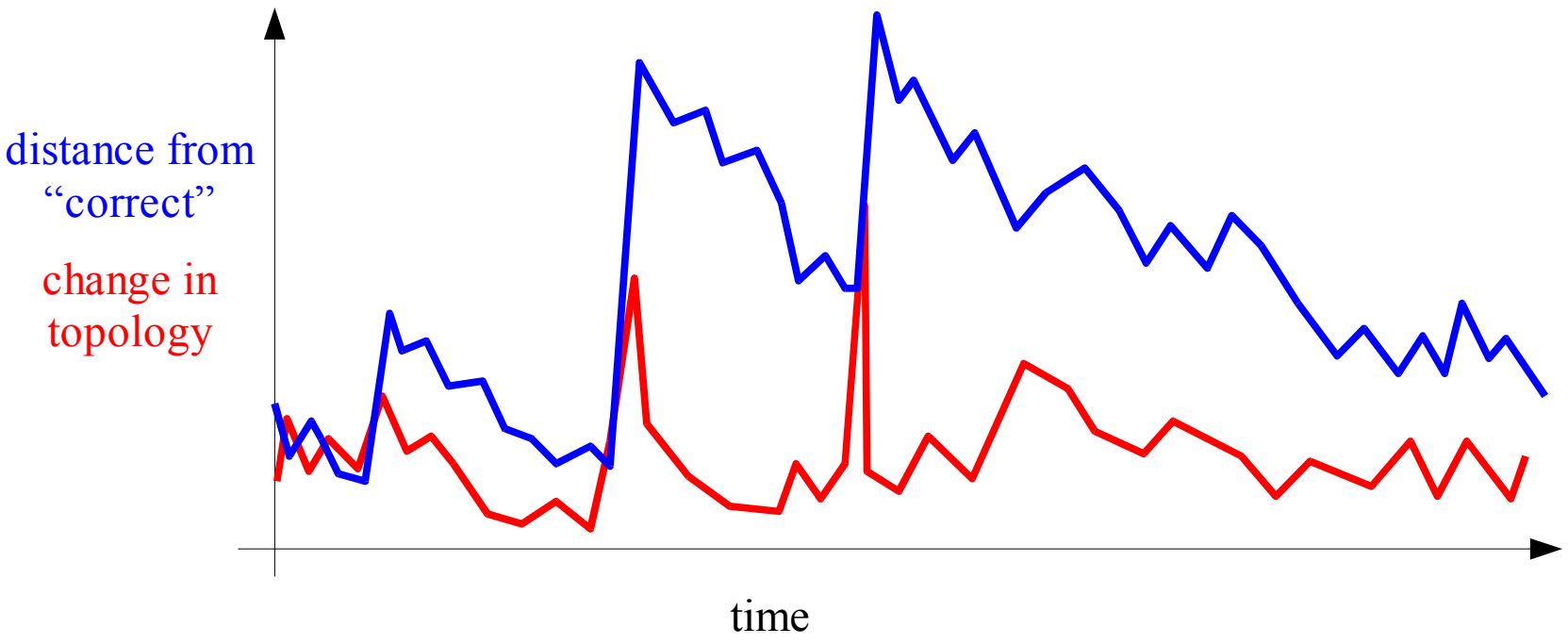
  Converge with cost O(F(k)) following *k* nodes failing or randomize state

Self-Stabilization = Impulse Response



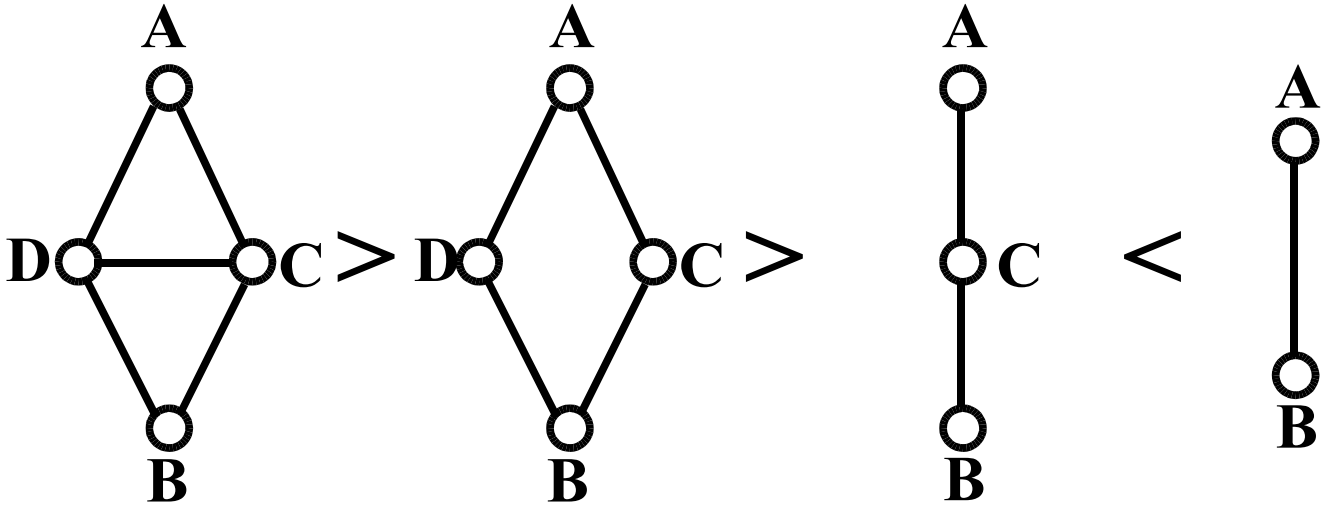
- What happens if the failures are not separable?

Goal: Continuously Self-Stabilizing



Noise Input: **T'(t)** [topology change]
Output Envelope: **A○T'(t)**

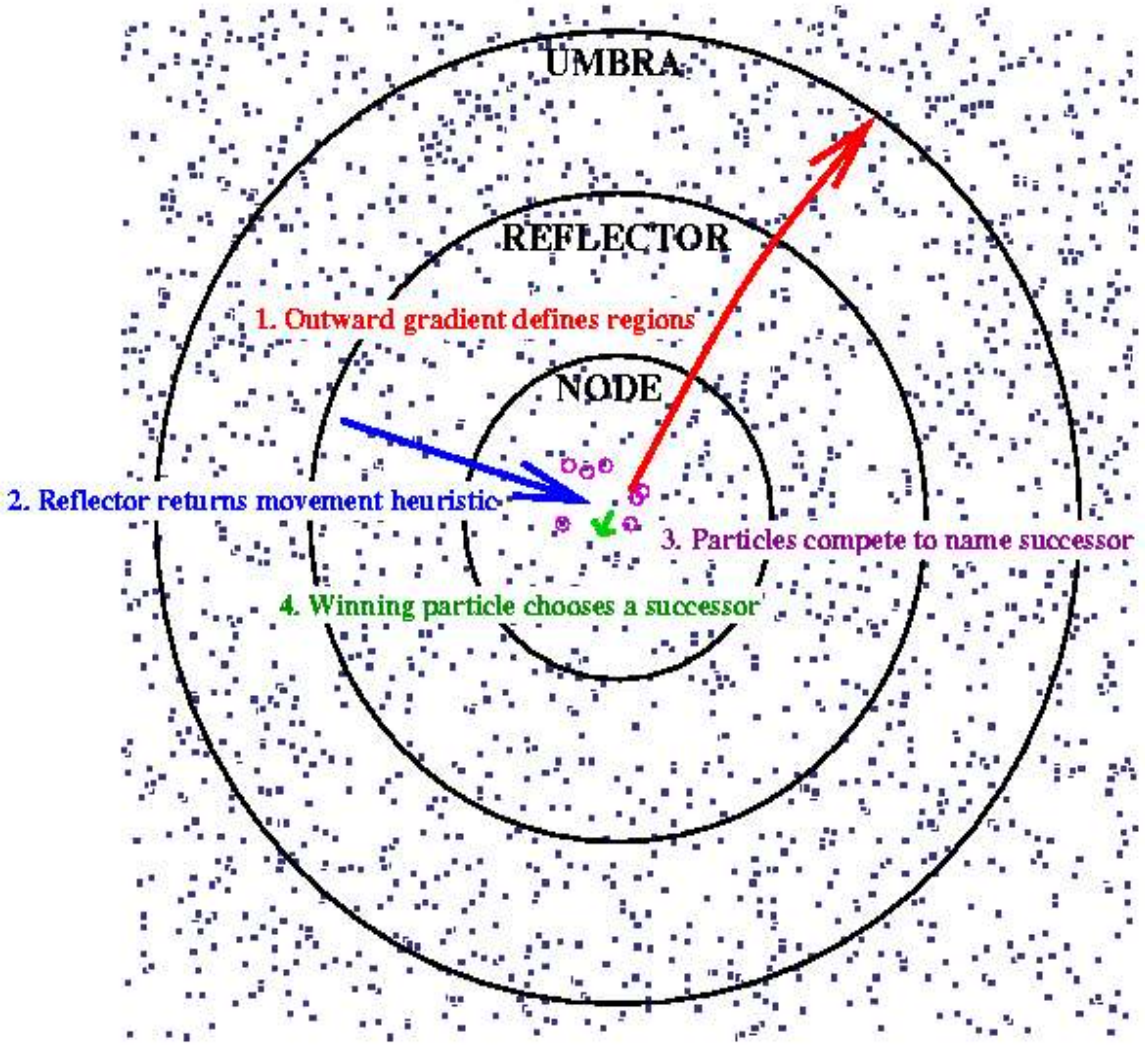
Conductance Metric



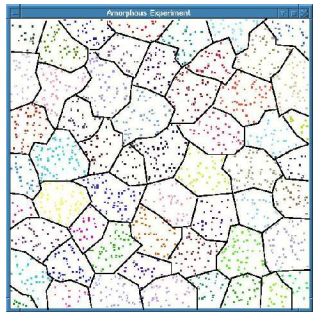
G(A,B)=1 T(t)=9.4 | G(A,B)=1 T(t)=7.333 | G(A,B)=0.5 T(t)=2.5 | G(A,B)=1 T(t)=1

T(t) = Sum of conductance G(i,j) for all pairs of nodes

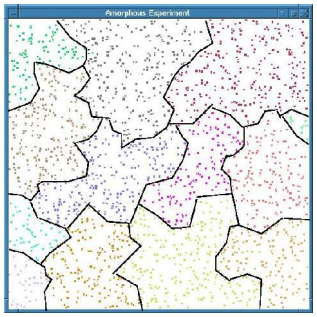
Persistent Node Primitive



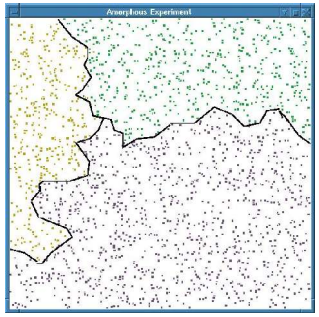
Persistent Node Hierarchy Algorithm



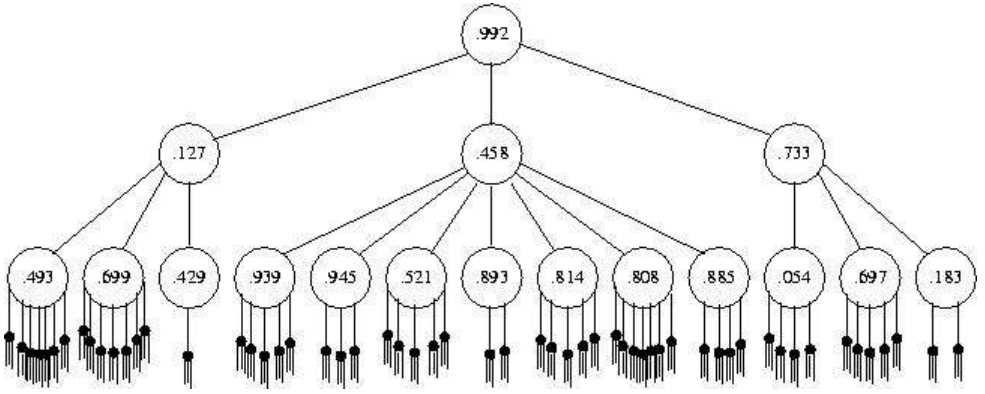
Level 1



Level 2



Level 3



- Self-Stabilizing
- Stopping failures cost O(max(diam(F),circum(F)))

Contributions

- Formulated Problem: Continuous Self-Stabilizing
  - Noise response as **A○T'(t)**
  - Discover algorithms with stable **A**
- Two Avenues of Investigation:
  - Metrics (e.g. conductance, radius&circumference)
  - Algorithms: PN family (e.g. hierarchy, routing)

Suggestions are welcome!