Shrink: A Tool for Failure Diagnosis in IP Networks

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Failures in ISP Networks

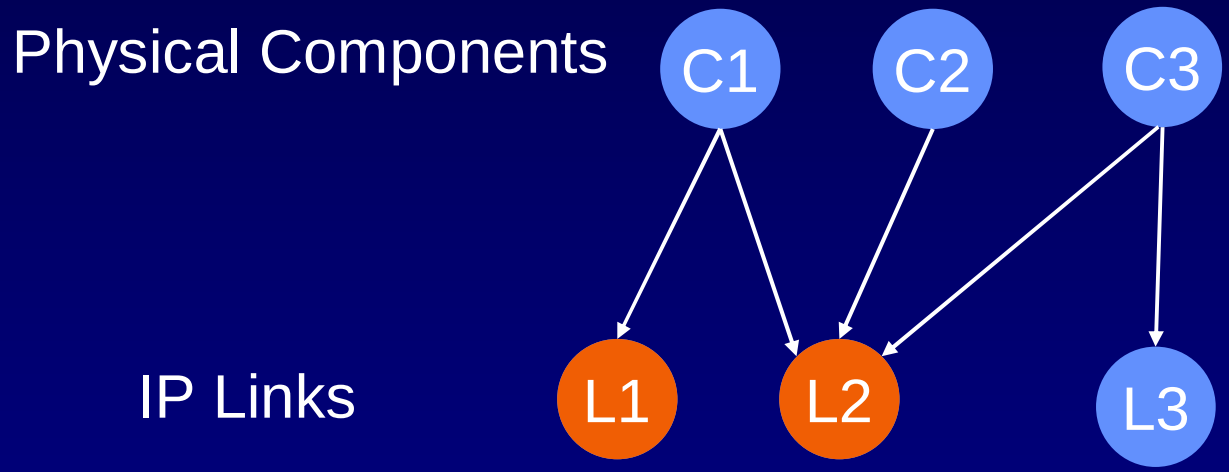
- An ISP network:
  - Logically, the network is a set of IP links
  - Physically, the network consists of fiber, optical cross-connects, and amplifiers …
- Failure at the IP layer are correlated with failures at the physical layer
- Failures are detected using SNMP messages that describe the state of IP links

Diagnosis Problem

- Given,
  - IP link status, a subset may have failed (logical failures), others are up
  - Database that maps IP links to underlying optical topology (physical components)
- Find the failed physical component(s)

Diagnosis Problem is Challenging (1)

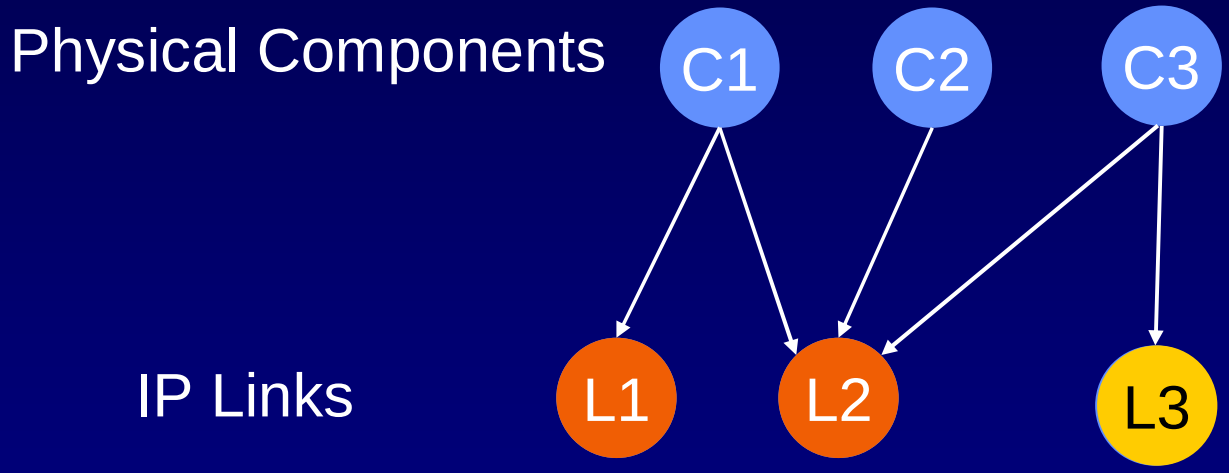
- Mapping IP-link failures to underlying physical failures is an under-determined problem



- When {L1,L2} fail, it is not clear which components have failed: either {C1} or {C1, C2}

Diagnosis Problem is Challenging (2)

- Errors in database that maps IP links to physical components
- Measurement noise caused by lost SNMP reports



- If Edge(C1,L2) is wrong, then C1 and C2 failed
- If report of L3 failure was lost → {C1,C3} failed now valid

Prior Solutions

- Min Set Cover
  - Finds the smallest number of component failures that explain all IP link failures
- Bayes Net Approach
  - Takes into account that different components have different prob. of failure
  - Finds the most likely component failures given the IP link failures

Our objective:
Find a more accurate solution that deals better with database errors and measurement noise

This Talk

- Shrink
  - Explicitly deals with database errors and measurement noise
  - Uses rich probabilistic models
  - Fast Inference algorithm
- Simulation results show that Shrink is more accurate than MinSetCov and BayesNet

Shrink Setup

Inputs

- Possibly inaccurate IP-to-Optical database
- Marginal prob. of component failure
- SNMP reports of IP link status,
  - e.g. {L1, L2} are up, {L3} is down, no report from {L4}

Shrink

Output

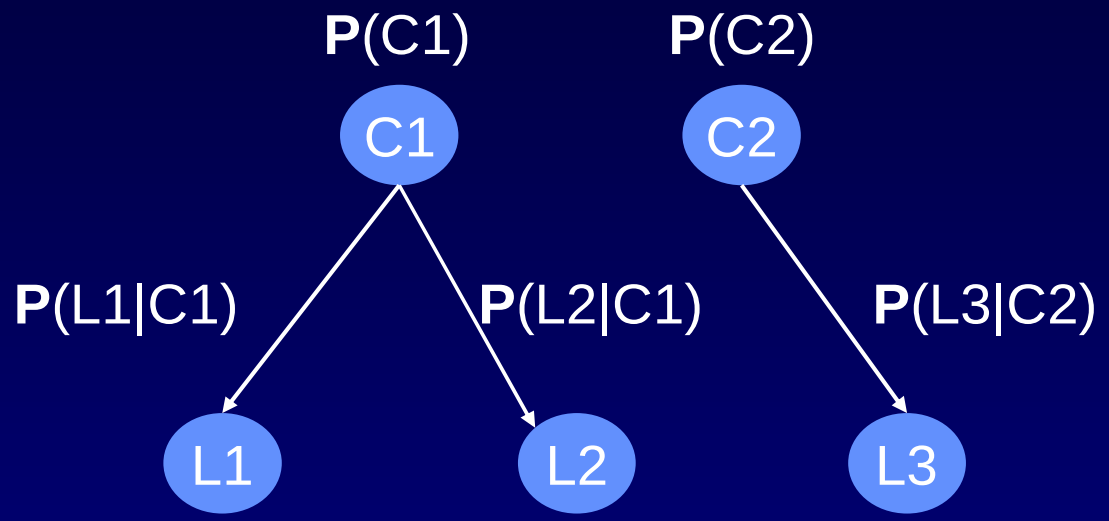
Most likely subset of component failures given link status

Shrink Has 3 Modules

1. Building the Bayesian Network
2. Augmenting the model with guess edges to deal with database errors
3. Inferring a diagnosis

Module 1:

Building a Probabilistic Model

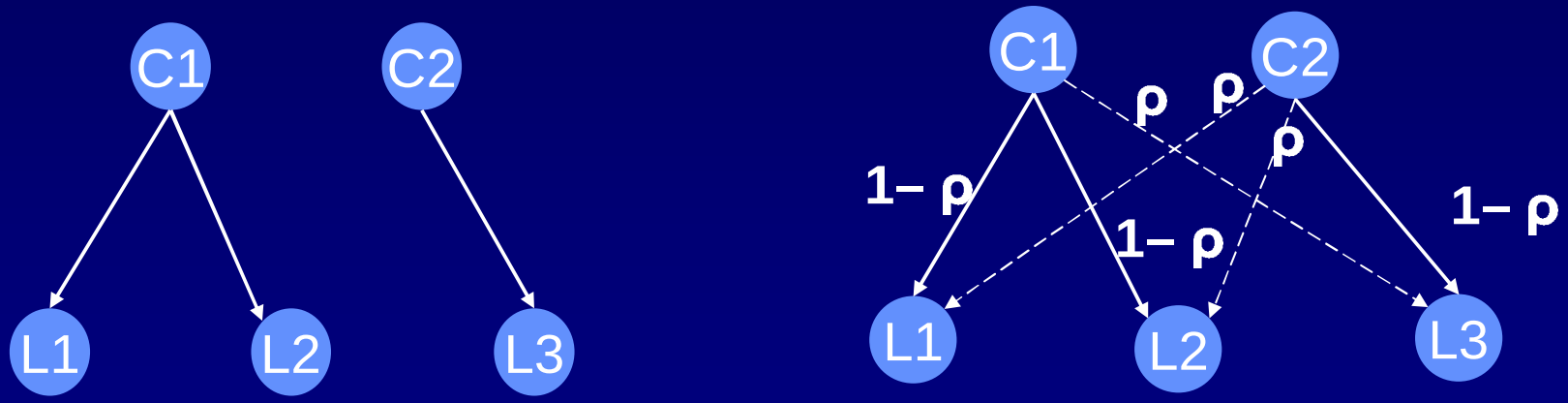


- Two-level graph– components on top, links at bottom
- Connect component to all dependent IP links
- Assign prior probability of component failure (independent)
- For each edge, assign prob. of link failure given component failure if known (noisy-or model)

Module 2:

Sub-Problem: Errors in database → Edge in model may not exist in reality (and vice-versa)

Solution: Augment the model with low-probability guess edges between un-connected components and IP links to deal with database errors



How does this help?

Why Augment with Guess Edges?

- Expands search to include explanations that were infeasible before, e.g. P(C2|L2,L3)
- Yet, prefer explanations that use few guess-edges, e.g., P(C1|L1,L2) > P(C2|L1, L2)

But, the augmented graph is complete → Standard Inference Algs. take exponential time

Module 3:

Shrink's Inference Algorithm

Likely that the correct explanation has only a small number of causes

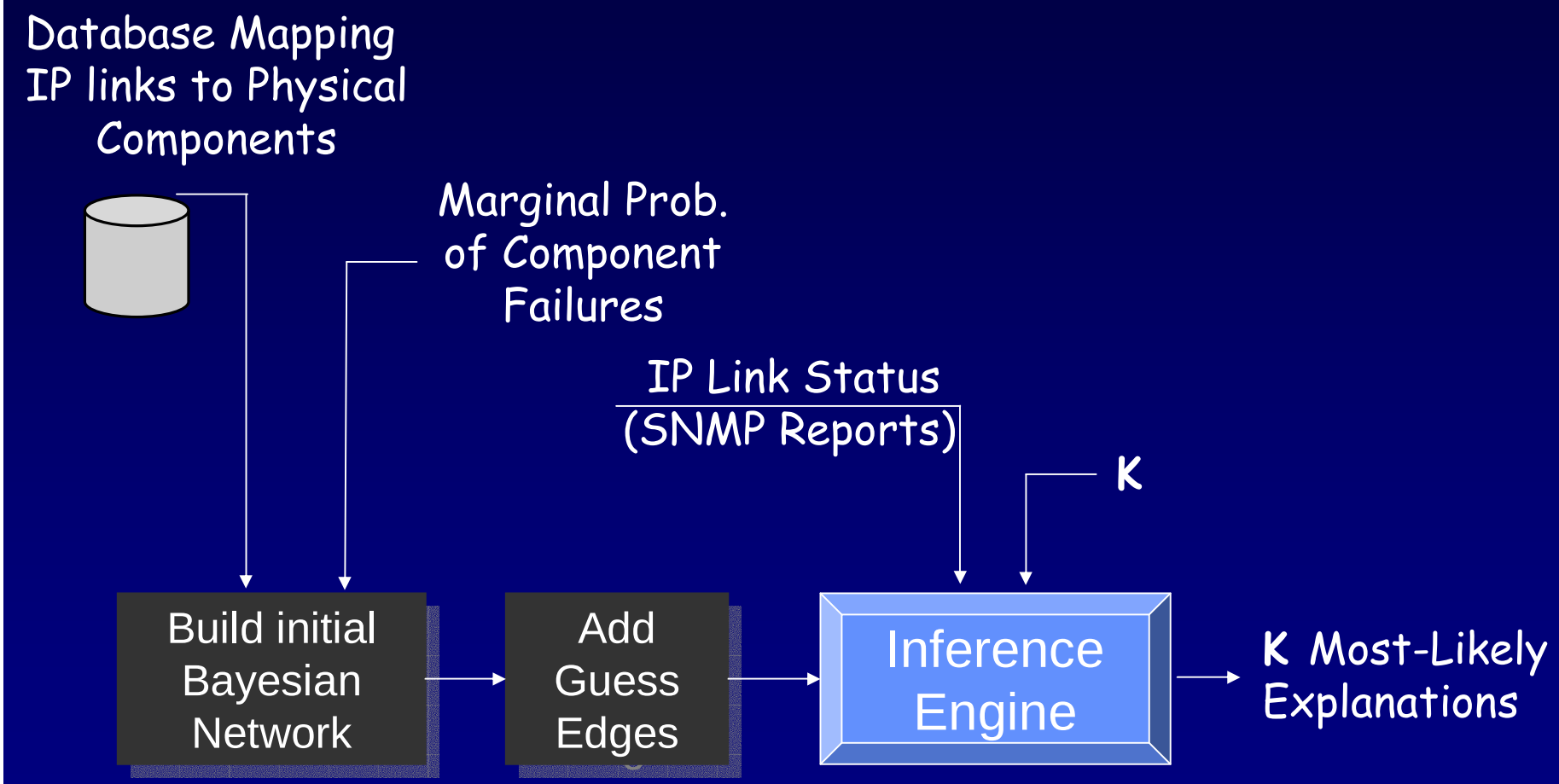
$$\arg \max_{C_1,\ldots,C_n} P(C_1,\cdots,C_n \mid L_1,\cdots,L_m)$$

subject to $number\ \ of\ \ \{C_i = 1\} \le q$

Characteristics of Alg.:

- Polynomial time
- Bounded Error (for q=3, error is smaller than 10^{-4})

Putting it Together

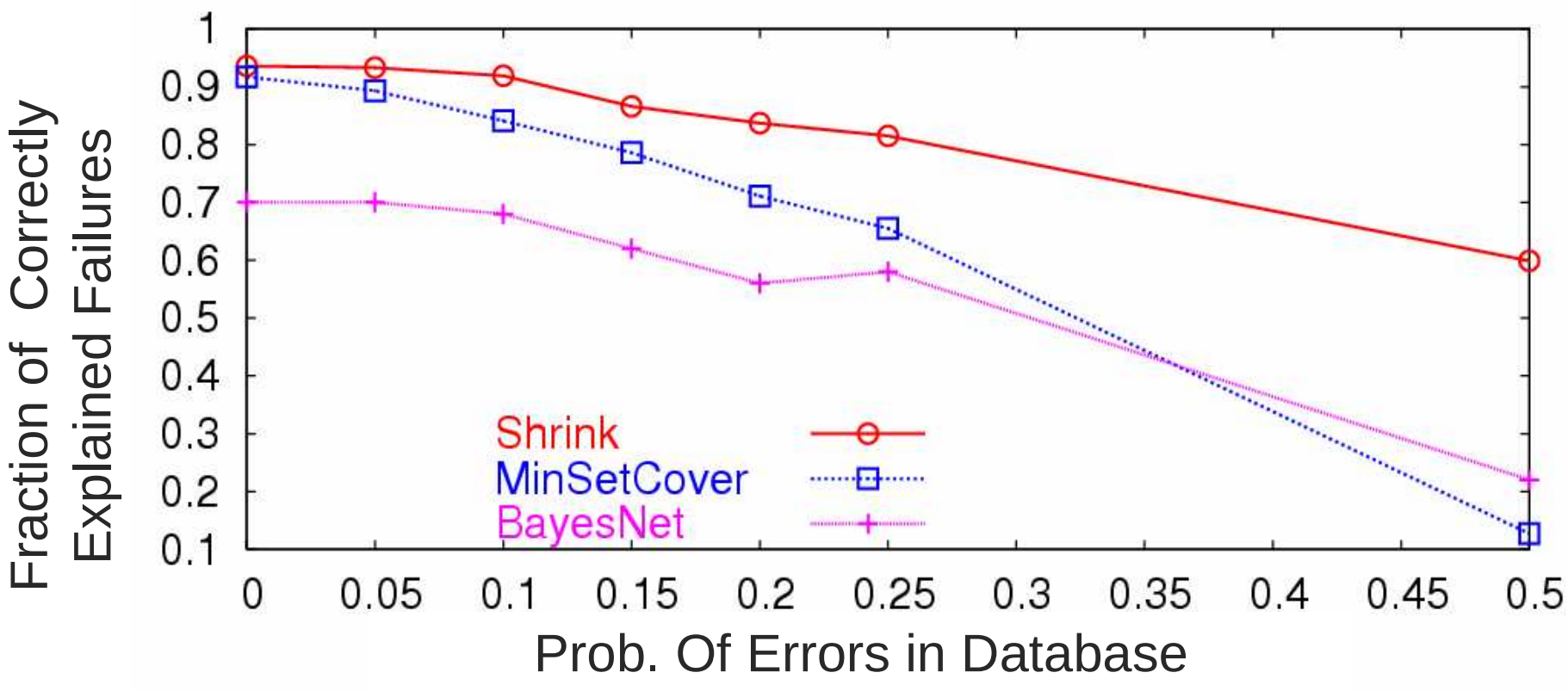


Performance

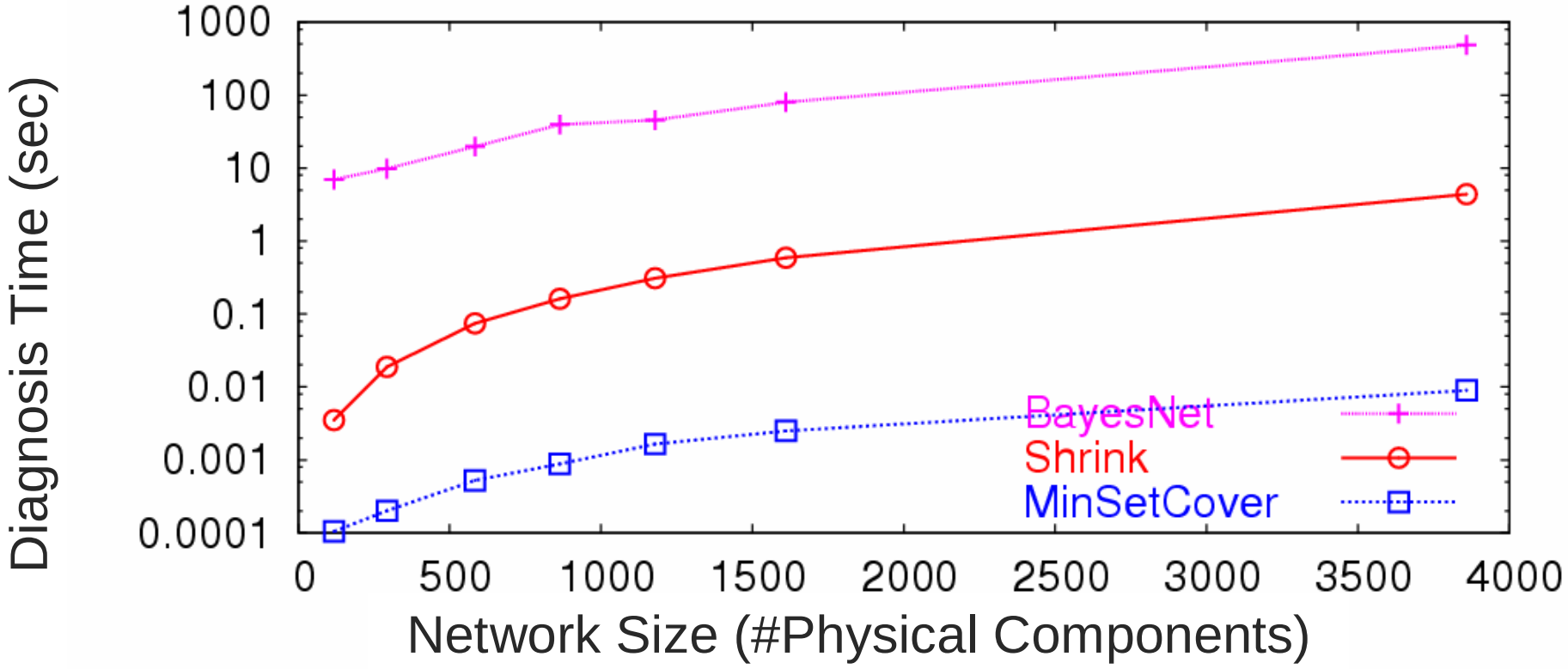
Simulation Setup

- Both the physical and logical topologies are generated using the BRITE simulator
- Use known statistics of component failure probabilities
- Randomly pick the components that fail
- Insert errors in database by adding a small number of unrelated links or deleting related ones

Shrink is More Accurate than Prior Approaches



Diagnosis Time



Despite exponential search space, Shrink 's inference algo. finds correct solution in a few seconds

Shrink's Contributions

- Augment Bayesian networks with guess-edges to model database errors
- Shrink's Inference Alg identifies most likely failures within a few seconds
- Shrink is more accurate than prior work
- More general – replace components with SRLGs, mapping database with any other configuration database