Measurement Methods for Fast and Accurate Blackhole Identification with Binary Tomography

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Users can collaborate to identify failures

- Users may want to assess ISP performance
  - Rank ISPs to choose best quality of service
  - Blame them for failures

- Users have limited access to network resources, but
- Can collaborate to identify failures
  - Limited to end-to-end probes
Monitoring helps applications improve QoS

- Improve hardware and deploy applications on gateways

- Need monitoring to perform peer selection and overlay construction
  - Connectivity
  - Bandwidth and jitter for streaming
  - Latency for games

- Need end-to-end probes to maintain overlay
Operators monitor to ease troubleshooting

- Blackholes are challenging to troubleshoot
- Persistent failures that raise no alerts
  - Router software bugs or misconfiguration
  - Problems in other networks

- Blackholes are detected by loss of end-to-end connectivity
  - Need for end-to-end measurements
Network tomography is promising

Detects and locates failures
Tomography steps

Collect status of paths

Combine end-to-end statuses

Run tomography
Tomography is sensitive to inaccurate inputs!

Transient losses cause detection errors

Unsynchronized measurements cause inconsistency
Remove inaccuracies to reduce false alarms

- **Failure confirmation**
  - Minimizes detection errors
  - Differentiates transient losses from persistent failures

- **Failure aggregation**
  - Aggregates unsynchronized measurement
  - Trades delay for consistency
Method

- **Analytical models**
  - How fast can we run confirmation?
  - What are the shortest failures we can identify?

- **Controlled experiments on Emulab**
  - Tomography is hard to evaluate: no ground truth
  - Measure failure identification rate and false alarms
  - Validate the analytic models

- **Deployment on PlanetLab and an enterprise VPN**
  - Assess the usefulness of the techniques in practice
  - No ground truth, but can still compare number of alarms
Failure Confirmation
Dealing with probe losses

- We need low overhead and quick confirmation.

Approach: send extra confirmation probes
  - How many?
  - When?
How and when to send confirmation probes

- Bursty losses modeled as a two-state Gilbert model
  - Two parameters: path loss rate and average burst length
  - Loss bursts durations are exponentially distributed

- Periodic confirmation probes minimize detection errors

- Optimization models to calculate number of confirmation probes and spacing between them
  - Minimizing total confirmation time
  - Minimizing number of confirmation probes
PlanetLab measurement setup

- 200 PlanetLab nodes probing each other for 12 days

- Paths are probed every 60 seconds

Run two confirmation schemes simultaneously
  - 5 back-to-back probes
  - 10 probes spaced by 200 milliseconds
Effect of failure confirmation in practice

10, 5, and 3 spaced

5 probes

3 probes

back-to-back

1 probe

Detection errors
Failure Aggregation
Short failures are impossible to identify consistently

### Very short failures

- **Cycle length**
- **Failure duration**
- **Detection Errors**

The relationship between failure length and cycle length:

\[
\frac{\text{failure length}}{\text{cycle length}}
\]

**Higher ratio = higher consistency**
Aggregation strategies

Basic aggregation
- After detecting a failure, measures all paths once and then runs tomography

Multi-Cycle aggregation (MC)
- Runs tomography only when $n$ consecutive cycles have identical measurements

Multi-Cycle Noise-Tolerant aggregation (MC-Path)
- Runs tomography with paths down for $n$ consecutive cycles
## Putting everything together – real deployments

### Number of alarms per day

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<th>Enterprise</th>
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Failure identification rate - Emulab

MC–Path
(n = 2)

Few false alarms

Rare false alarms

Identification Rate

Failure Length / Cycle Length
Summary

- Tomography algorithms need accurate inputs

- Failure confirmation
  - Differentiates transient losses from persistent failures
  - Minimizes the number of probes and delay

- Failure aggregation
  - Aggregates measurements from multiple vantage points
  - Trades delay for consistency
Thank you!
Confirmation removes false alarms – Emulab

Basic aggregation
Trading delay for higher consistency - Emulab

- Abilene topology and synthetic failures
- No confirmation: many detection errors

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Putting it all together - Emulab

![Graph showing comparison of Basic, MC-Path (n=2), and MC (n=2) for Identification Rate and Total False Alarms against Failure Length / Cycle Length.](image)
Bursty losses modeled as a two-state Gilbert model

- Loss bursts durations are exponentially distributed
- \( \text{Prob}(\text{losing confirmation probe} \mid \text{previous probe lost}) \)
Short failures are impossible to identify consistently

- Failures shorter than one cycle
  - Cycle length
  - Time
  - Failure duration

- Failures shorter than two cycles

- Failures longer than two cycles
Detection errors can also create false alarms

Detection errors reduce consistency

\[
\text{information} = \frac{\text{failure length}}{\text{cycle length}}
\]

higher ratio = higher consistency
Future Work

- Tomography algorithms also need up-to-date topologies

- Develop confirmation and aggregation techniques for non-binary metrics like loss rate and bandwidth

- Deploy these techniques in conjunction with tomography algorithms to build a real-time system
## Putting everything together - real deployments

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<tr>
<td>MC-PATH</td>
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