LightGuardian:
A Full-Visibility, Lightweight, In-band Telemetry System Using Sketchlets

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Background

- measurement is central to successful network operations
Background

Packet lost

What’s wrong
Background

High latency

What's wrong
Background

• measurement is central to successful network operations

• **full-visibility**
  
  • per-hop *flow-level* information for *all flows*

• **lightweight**
  
  • computation, memory, bandwidth

• **robustness**
  
  • link failures, device failures
Background

- existing solution
  - sampling
  - probing
  - sketch-based
  - in-band

\{ (currently) lack of **full-visibility** \}

\{ (currently) lack of **lightweight** \}
LightGuardian Overview

• Accurate & versatile device-local sketches

• In-band telemetry with sketchlets

• Incremental network-wide aggregation
LightGuardian Overview

- Accurate & versatile device-local sketches
LightGuardian Overview

• In-band telemetry with sketchlets
LightGuardian Overview

- In-band telemetry with sketchlets
LightGuardian Overview

• Incremental network-wide aggregation
Device-local Sketch Design: SuMax

- record both of the sum value and the maximum value
Device-local Sketch Design: SuMax

- record both of the **sum** value and the maximum value

SuMax Sketch

\[ \langle f, +1 \rangle \]

\[ 14 \rightarrow 4 \rightarrow 20 \]

\[ 9 \rightarrow 8 + + \leftarrow 13 + + \]

\[ 3 + + \]

\[ 19 + + \]
Device-local Sketch Design: SuMax

• approximate conservative update strategy

SuMax Sketch
Device-local Sketch Design: SuMax

- record both of the sum value and the **maximum** value
Transmission of Sketchlets

SuMax sketch $S$

Switch $X$
Transmission of Sketchlets

Transport Layer

TCP Header

device ID

sketchlet ID

Application Layer

packet

carry-bit

active-bit

Idle sketch $S_1$

Active sketch $S_2$

Switch $X$
Transmission of Sketchlets

• Sketchlets Selection: $K$-chance Selection

- just takes $\lceil \log(k + 1) \rceil$ bits (2~3 bits)
Reconstruction and Analysis

- Incremental reconstruction

$$f_1 = \min(9, \infty, \infty, 10) = 9$$

valid 😊
Reconstruction and Analysis

• Incremental reconstruction

\[
\begin{align*}
\hat{f}_1 &= \min(9, \infty, \infty, 10) = 9 \\
\hat{f}_2 &= \min(\infty, \infty, \infty, \infty) = \ldots \\
\text{valid} & \quad \text{🙂} \\
\text{invalid} & \quad \text{:-(}
\end{align*}
\]
Reconstruction and Analysis

• Locating Inflated Latency
• Locating Packet Drops
  • Blackhole
  • Loop
  • Random packet drops
• Locating Abnormal Jitters
• Finding Abnormal Forwarding Path
Experimental Results

• Testbed
  • Tofino-40GbE
Experimental Results

• How accurate can our SuMax sketch measure per-flow statistics?

• Flow size estimation
Experimental Results

• How accurate can our SuMax sketch measure per-flow statistics?
• Flow size estimation
• Cardinality estimation
Experimental Results

• How accurate can our SuMax sketch measure per-flow statistics?
  • Flow size estimation
  • Cardinality estimation
  • Entropy estimation
Experimental Results

- How accurate can our SuMax sketch measure per-flow statistics?
  - Flow size estimation
  - Cardinality estimation
  - Entropy estimation
  - Delay distribution

![Graph showing WMRE vs Memory usage (KB)]
Experimental Results

• How accurate can our SuMax sketch measure per-flow statistics?
  • Flow size estimation
  • Cardinality estimation
  • Entropy estimation
  • Delay distribution
  • Maximum inter-arrival time
Experimental Results

• How accurate can LightGuardian detect network anomalies?

• Locating blackholes
Experimental Results

• How accurate can LightGuardian detect network anomalies?

• Locating blackholes

• Locating loops
Experimental Results

• How accurate can LightGuardian detect network anomalies?
  • Locating blackholes
  • Locating loops
  • Locating abnormal jitters

![Graph showing F1-score vs Memory usage (KB) with different thresholds]
Experimental Results

• How much is the overhead of sending and aggregating sketchlets?

• FCT
Experimental Results

• How much is the overhead of sending and aggregating sketchlets?
• FCT
• Per-hop latency
Experimental Results

• How much is the overhead of sending and aggregating sketchlets?
  • FCT
  • Per-hop latency
  • Bandwidth overhead
Experimental Results

• Is LightGuardian resilient to network failures?

• Full-Recovery Rate (FRR):
  • the probability of recovering all sketches

• Recovering-Sketch Rate (RSR):
  • the ratio of the number of recovered sketches to the number of all sketches
LightGuardian

- **full-visibility**: deploy SuMax sketch, monitor various per-flow per-hop information for all flows
- **Lightweight**: use only 0.07% total bandwidth capacity
- **Robustness**: incremental reconstruction
Thank you!

• Our code is open-source!

• https://github.com/Light-Guardian/LightGuardian

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