Network Radar:  
Tomography from Round Trip Time Measurements  

Yolanda Tsang$^{1,2}$, Mehmet Yildiz$^2$, Paul Barford$^3$, Robert Nowak$^{1,2}$

1. ECE, Rice University  
2. ECE, University of Wisconsin - Madison  
3. CS, University of Wisconsin - Madison
Unicast Network Tomography

Normal
Abnormal

sender

receivers

Network Radar
Unicast Network Tomography

From edge-based traffic measurements, infer internal link-level loss rates and delay statistics.
Packet Pair Approach

Correlations in closely (time) spaced packet pairs allow us to resolve link-level performance.
Delay Variance Tomography

Measure end-to-end delays of packet-pairs

\[ \sigma_1^2 = \text{cov}(d2, d3) \]

Packets experience identical delays on link 1

\[ \sigma_2^2 = \text{var}(d2) - \sigma_1^2 \]

\[ \sigma_3^2 = \text{var}(d3) - \sigma_1^2 \]
Basic Idea

sender

receivers
Round Trip Time (RTT)
TCP Three-way Handshake

Sender

Time

RTT

SYN

SYN-ACK

Generation delay

SYN-ACK

Receiver

Transmission
Propagation
Queuing

SYN: Synchronize

SYN-ACK: SYN Acknowledgement

RST: Reset

IMC 2004

Network Radar
Network Radar

Send closely time-spaced packets to two different receivers
Example (Delay Variance Estimation)

Assumptions:
• Independent delay measurements
• Identical delays on shared links

Measurements:

\[ y \equiv \{ y_1(k), y_2(k) \}_{k=1}^{N} \]

where

\[ y_1(k) = d_s(k) + d_1(k) \quad \text{and} \quad y_2(k) = d_s(k) + d_2(k) \]

\[ \sigma_s^2 = \text{var}(d_s) = \text{cov}(y_1, y_2) \]
Example (Continue)

Denote $\hat{\rho}$ as an unbiased estimator of the variance of the shared link

$$\hat{\rho} \equiv \frac{1}{N - 1} \sum_{k=1}^{N} (y_1(k) - \bar{y}_1)(y_2(k) - \bar{y}_2)$$

$$E[(\hat{\rho} - \rho)^2] = O(N^{-1})$$
Emulation Test-Bed Experiment

Wisconsin Advanced Internet Laboratory

Sender

xT: Cross Traffic generator
R: Router (Cisco 3600 series)
S: Packet Sniffer

Receiver 1
Receiver 2

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Results
Localization

\[ \sigma^2 = \text{cov}(y_1, y_2) - \text{cov}(y_1, y_3) \]
Future Work & Challenges

• Future Work
  – Validate software in the real Internet
  – Improve time-stamping mechanism in hardware
  – Develop publicly available Network Radar tool
  – Infer topology from radar measurements

• Challenges
  – “Signal” to “Noise”
  – Back-to-back packet generation
  – Accurate + precise time-stamping
Thank you!

Questions?