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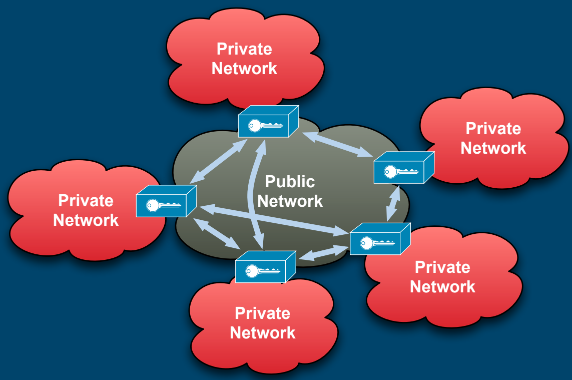
Attack-Resistant Distributed Time Synchronization for Virtual Private Networks

Overview

- Distributed Services for Distributed VPNs
- Objectives for Robust Time Synchronization
- Approach
  - Offset Estimation
  - Synchronization
- Evaluation
- Conclusion & Outlook

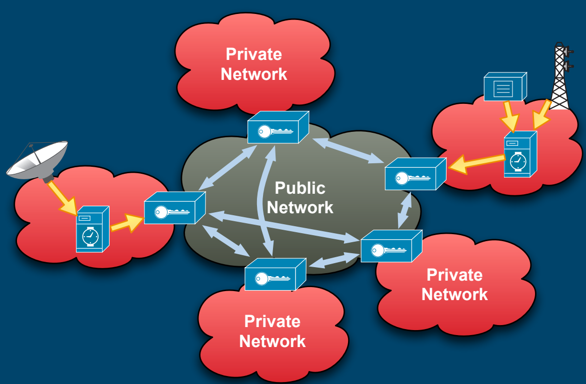
Distributed Services for Distributed VPNs

- Large VPNs, >100 end-points
- For scalable, robust operation distributed configuration
- But what about the centralized management?



Distributed Services for Distributed VPNs

- Secure time information available only in some places
- Must be distributed in the VPN
- NTP etc. would create exposed points



Objectives

- Operation in global environment (use no broadcast etc.)
- Synchronize internally & externally
- Integrity (against internal attackers)
- Robustness (jitter, asymmetric paths, perhaps DoS attacks)
- Scalability

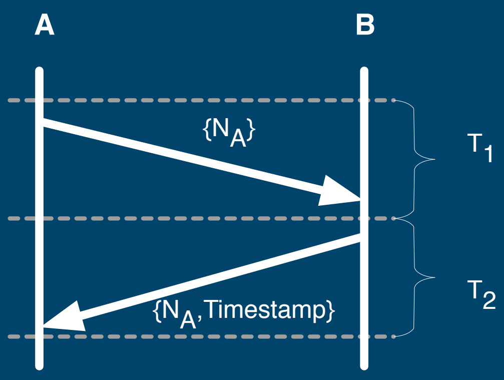
Approach – Overview

- All nodes periodically
  - Exchange time information
  - Filter invalid data
  - Adapt towards measured differences
- Note: Also done in some WSN approaches, but do so more robust (as this works in this scenario)

Approach – Offset Estimation

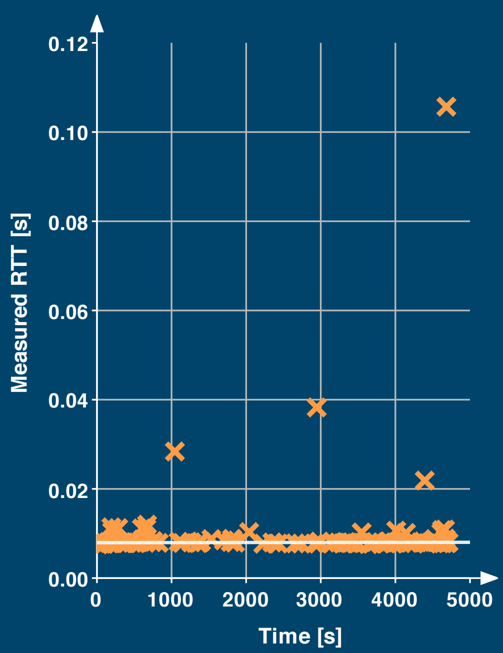
- Measure RTT and time over encrypted tunnel
- Problem: T_1 and T_2 may be different due to:
  - Jitter
  - Queuing Delays
  - Asymmetric Paths

→ Multiple measure-ments to filter out all invalid data we can



Approach – Siegel-Estimators

- Estimate RTTs and time offsets by linear functions
- Robust estimation by using repeated median
- Resistant against up to 50% outliers
- Slopes indicate "confidence"



Approach – Reducing the History

- Longer history → More resistant against short term changes
- But
  - Slower adaptation
  - More computations required
- History thinned out over time using Zipf distribution
- Newer values are more emphasized
- Old values still have an influence

Synchronization Step

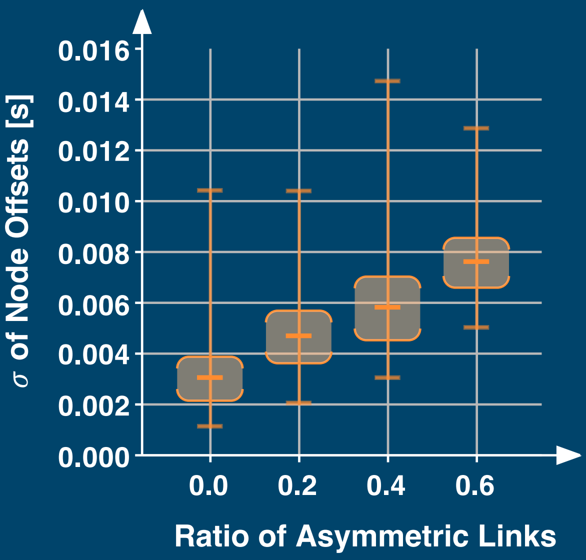
- Offset estimates of different partners are aggregated
- Weighted median assures bad estimates and outliers have no influence
- Dampening assures over compensation

```
Input: estOffsets, confidences
medOffset ← wMedian(estOffsets, confidences);
if medOffset < minAdjOffset then
    return;
adjustTime(medOffset · dampFactor);
foreach neighbor n do
    offsets[n].adjustBy(medOffset · dampFactor);
```

Evaluation – Global operation

- Uses unicast only → might work globally
- But: What about asymmetric paths?
- Experiment:
  - 32 runs
  - Internet Delays
  - γ-distributed Jitter

→ No significant influence!



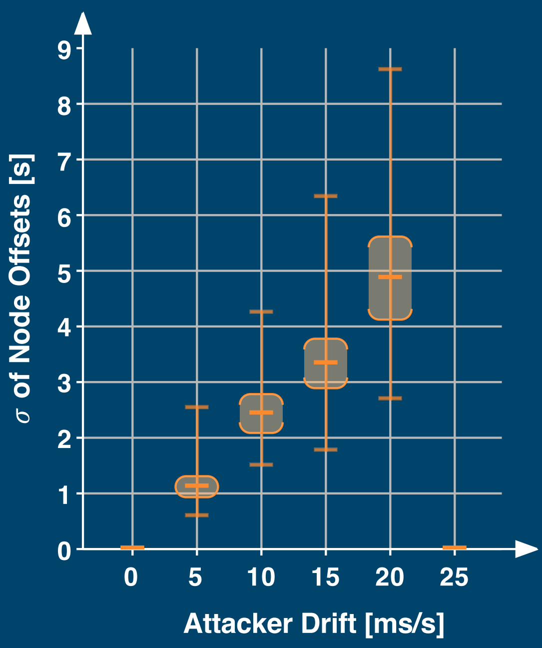
Evaluation – Synchronization

- Adaptation guaranteed, if and if graph of synchronization partners is
  - Strongly connected
  - No sub-graphs exist where all nodes are more connected to the sub-graph than to the outside
- Fortunately: This is the case for expander graphs and thus most peer-to-peer systems
(Short proof in the paper)

Evaluation – Integrity

- Which influence have 10% of attackers (in a VPN with 100 nodes)?
- Attackers try to circumvent filter by gradually increasing reported offsets
- Measured σ after 500 synchronization steps

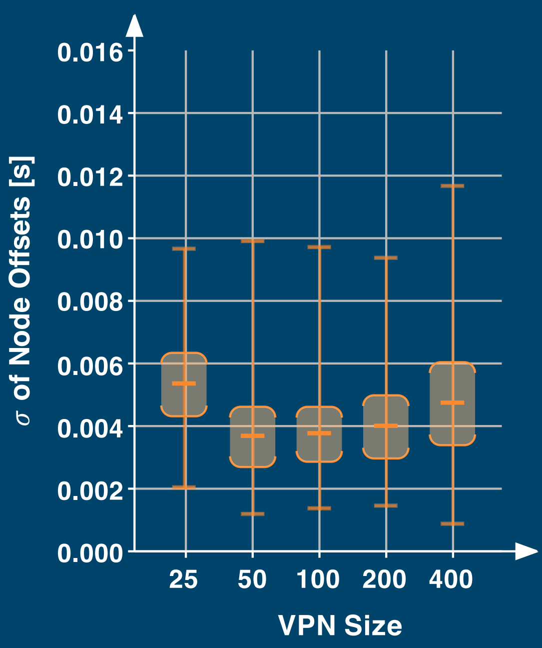
→ Some nodes are pulled away, but as offset increases filter works



Evaluation – Scalability (I)

- How does VPN size affect synchronization precision?
- Measured σ in steady state for growing VPN size

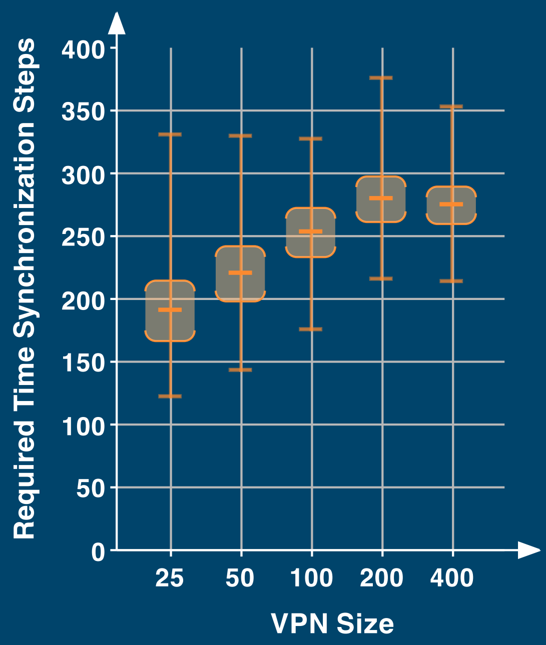
→ No significant impact!



Evaluation – Scalability (II)

- How does VPN size affect time to stabilization?
- Measured steps until error < 0.1s for growing VPN size

→ Sub-linear impact despite logarithmic scale!



Conclusion & Outlook

- Scalable & robust approach to synchronize clocks in distributed systems
- Can be applied always if network graph has expansion properties
- Optimizations still possible, e.g.:
  - Weighting of confidence factors
  - Blacklisting to avoid adaptive attackers

Thank you for your attention!

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