Graph-Prints: A Contextual, Model-free, Multi-Scale Network Analysis Framework for Characterizing Network Flow Data

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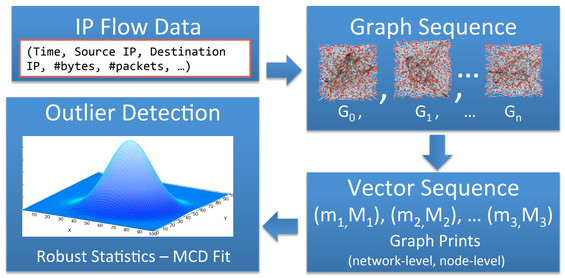
Anomaly Detection Workflow

Given a sequence of graphs, $\{G_i\}_{i=1}^N$ discover anomalies at multiple related levels



Creating Graphs from Network Flow

- Nodes are IP addresses
- Directed edges are aggregate flows, colored red if both ports >= 1024 black otherwise
- Time windows of 31 seconds with 1 sec overlaps

Test Data Set

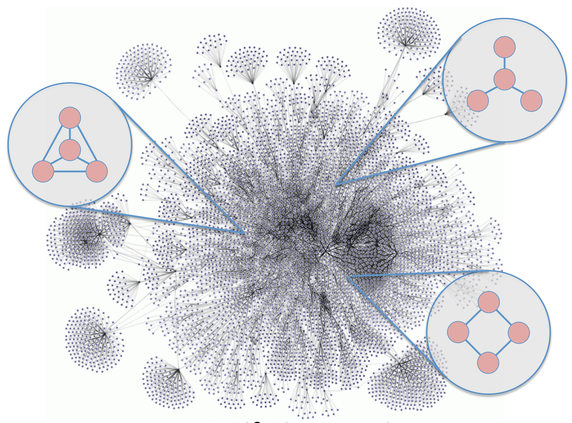
Bit Torrent (BT) Traffic Data Set

- Ambient traffic collected at Oak Ridge National Laboratory using Argus**
  - 5 hours of traffic, 3 million flows
- Anomalous BT traffic collected from personal laptop using Argus
  - 30 min BT traffic, 18k BT flows
- Implanted BT traffic data into ambient data by matching IP, router, and timestamps

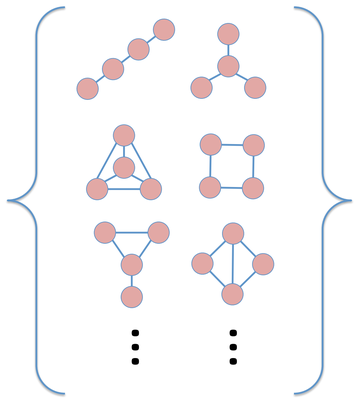
** www.qosient.com

Graph Prints Method

Network Motifs: "Network Building Blocks"



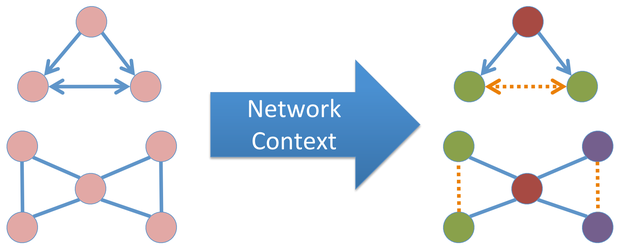
Motif Discovery in Large Network*



Network Motifs

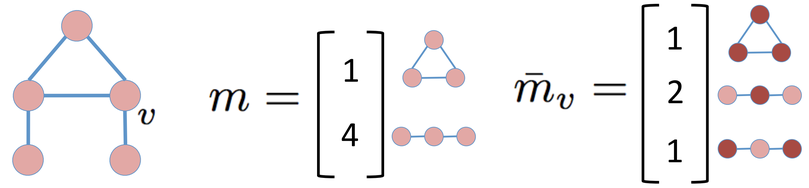
Graph Coloring: "Contextual Information"

- Different Entities
- Different Interactions
- Recognize contextual patterns



Multi-Scale Graph Prints

- Network Level: motif counts, m
- Node Level: motif automorphism orbit counts, $M = \{\bar{m}_{v_1} \cdots \bar{m}_{v_n}\}$
- Graphs to Vectors: $\{G_i\}_{i=1}^N \to \{(m_i, M_i)\}_{i=1}^N$



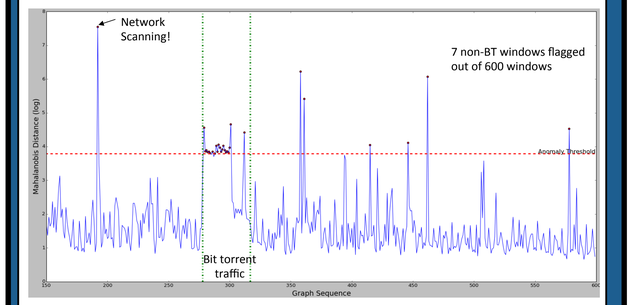
Example Network | Network Motif Count | Motif Automorphism Orbit Count for v

* www.yworks.com

Results

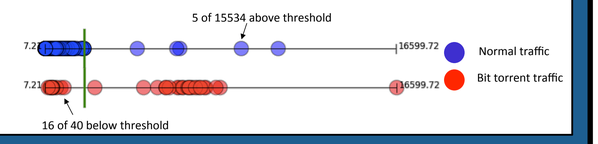
Graph Level Anomaly Detection

- Fit motif vectors to normal distribution using Minimum Covariance Determinant, a robust statistical fitting
- Score vectors by mahalanobis distance and declare anomalous if above a threshold



Node Level Anomaly Detection

- Cluster non-BT node orbit vectors using k-means with gap statistic
- Compute distance to nearest centroid for BT and non-BT node orbit vectors



References

1. Tijana Milenkovic and Natasa Przulj, "Uncovering biological network function via graphlet degree signatures", Cancer Informatics 2008, 6:257-253.
2. Rousseeuw, Peter J., and Katrien Van Driessen. "A fast algorithm for the minimum covariance determinant estimator." *Technometrics* 41.3 (1999): 212-223.

Acknowledgements

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