CCICADA

Command, Control, and Interoperability Center for Advanced Data Analysis

A Department of Homeland Security Center of Excellence

Graph Evolution Over Time: Detecting Anomalies in Networks

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Motivation

- What is the problem?
  - Anomalous activity (e.g., element failures, security-related problems) likely degrades network reliability and performance
- Who cares?
  - Those who supply and consume network services
- What makes this problem difficult?
  - Centralized network performance information is often not directly available
  - No model for normal network operation
  - Large amounts of data to process
- What does this presentation offer?
  - Overview of network activity monitoring
  - Introduction to our work in anomaly detection
  - Invitation for collaboration

Anomaly Examples

- Non-security related
  - File server failure
  - Broadcast storm
  - Congestion due to element failure
- Security related
  - Denial of service attack
  - Botnets

Background

- Complex networks are composed of many individual entities, data collection done in various ways
  - Probes
  - Entity-based, use knowledge of topology
- Different working environments
  - Non-cooperative networks, multiple administrative domains
  - Single administrative domain
- Large amounts of data are collected to achieve basic understanding
  - Must be measured, analyzed, synthesized to extract network information

In the CCICADA Mix

1. Collecting and building knowledge from data
2. Enriching knowledge and inference

   Project 5: Hypothesis Formation and Anomaly Detection.
3. …

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Network Data

- What are sources of network data?
  - Probing tools
  - Packet filtering, packet headers
  - Network management protocols
- What is normal traffic behavior?
  - That is hard to say

Challenges

- Non-stationary data
- Large data-sets in short time intervals
- Determining length time interval
- Staleness of older data points
- Lack of labeled data for validation
- Danger of hypersensitivity or over-fitting

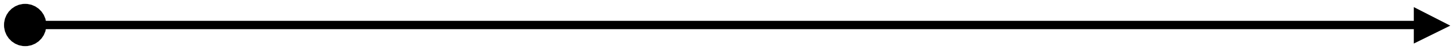
Previous Approaches

- Rule-based, case based reasoning
  - Build records of past anomalous instances
  - Dependence on past information
- Pattern matching
  - Construct symptom-specific feature vector
  - Use patterns of known attacks for detection
- Finite state machine modeling
  - States are sequence of alarms
  - Possible explosion of state space
- Signal processing

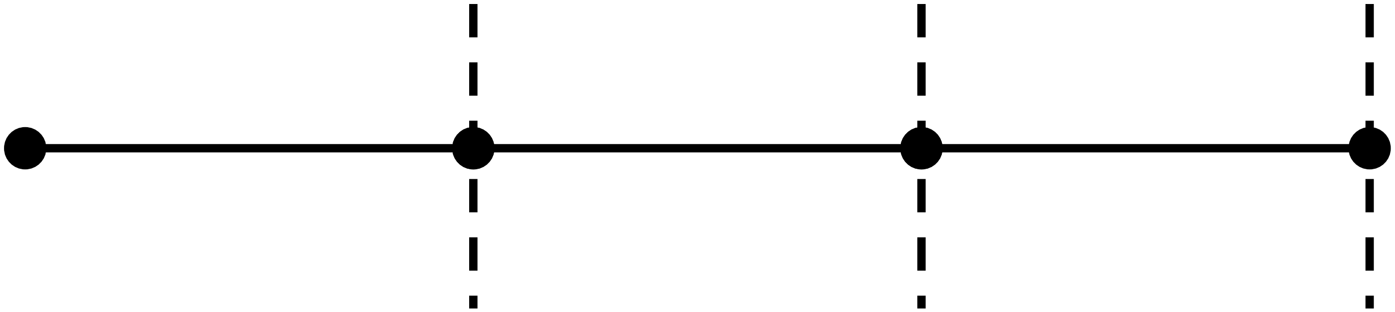
Performance Metrics

- Subject to Type I and Type II errors
  - Mean time between false alarms
  - Time until anomaly detection

Time



Evolution of a dynamic graph



Series of static graphs

Graph Characteristics

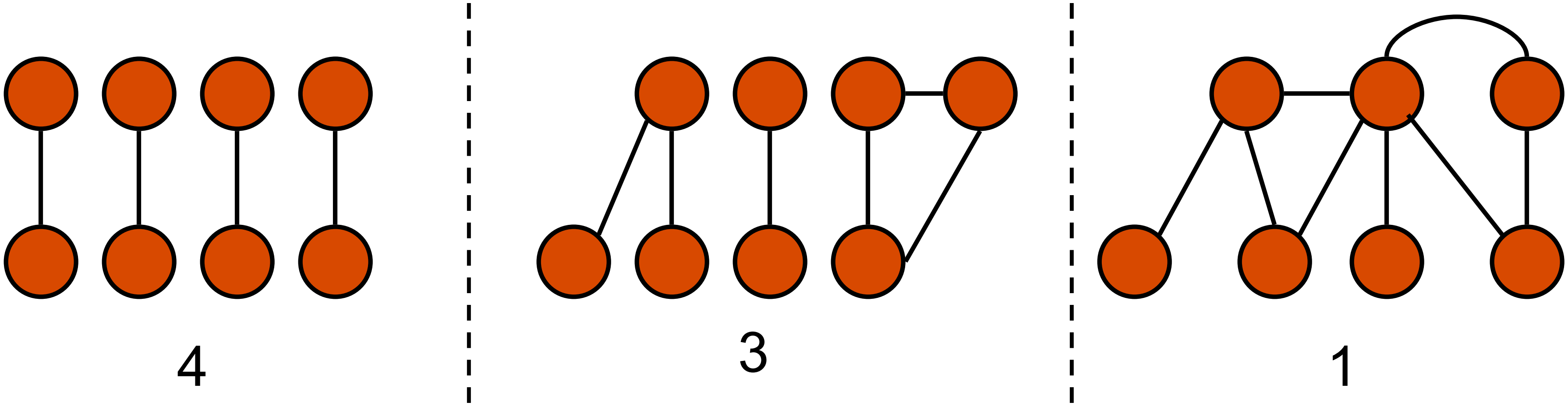
- Static graph
  - In-degree distribution
  - Out-degree distribution
  - Distribution sized of weakly connected components
  - Diameter of graph
  - Clustering coefficient
- Evolving graph
  - Evolving diameter
  - Densification process

Method

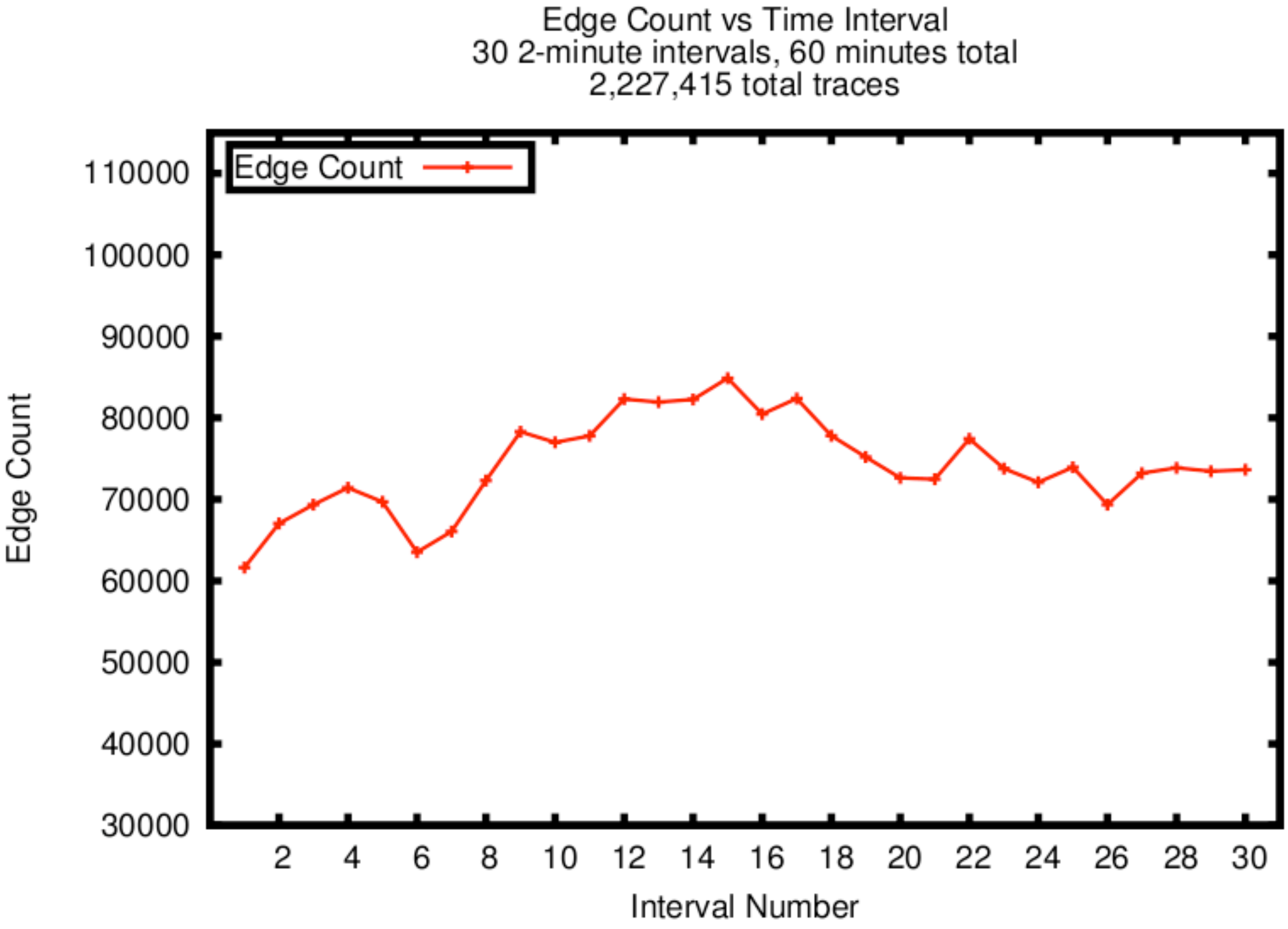
- Online change-point detection given source-destination data
  - Take samples of fixed time interval
  - Compute static graph statistics for each interval
  - Make a decision independently for each interval

Example

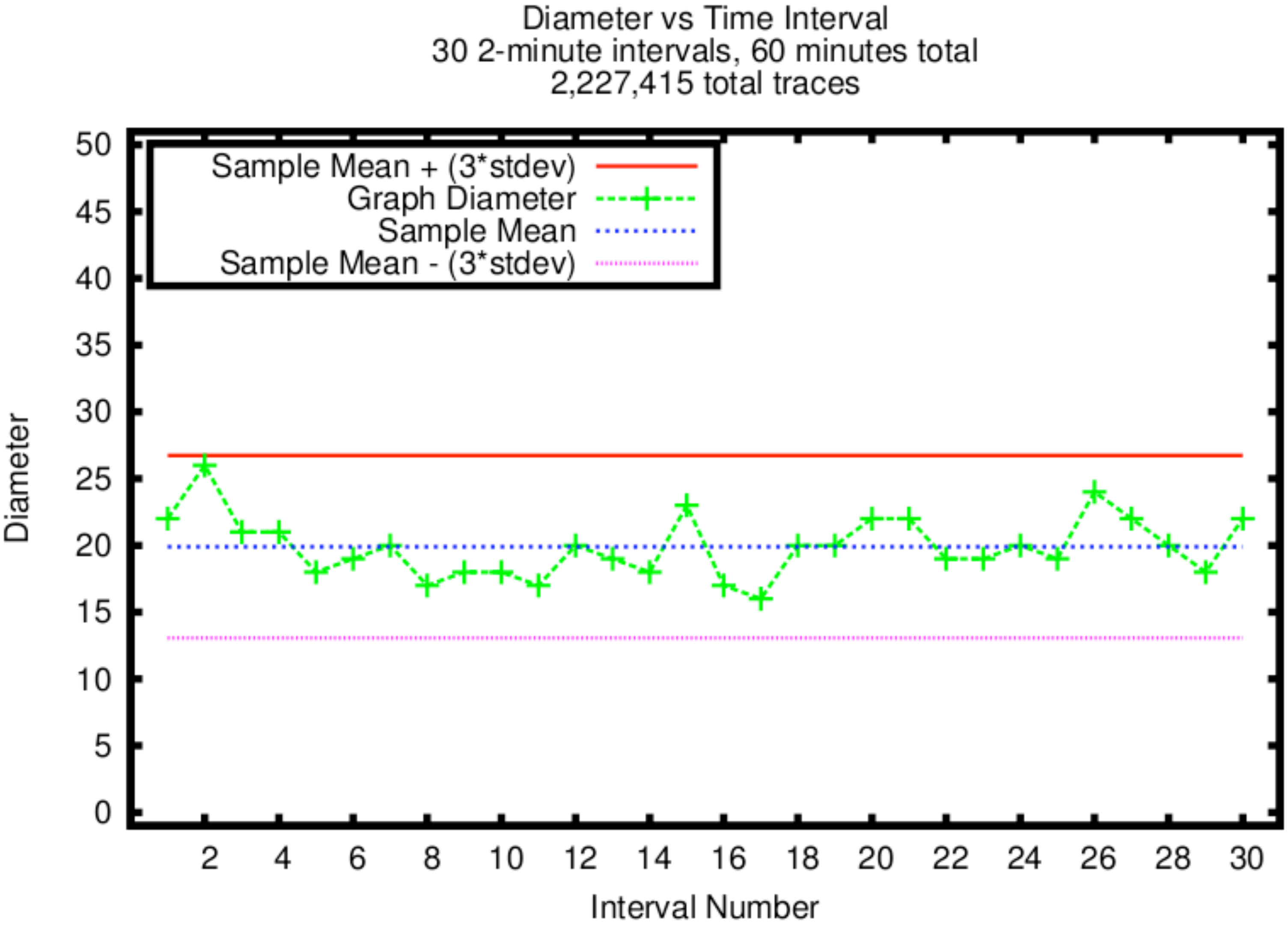
- Detecting change in network characteristics among a series of data points
  - – WCC example for communication graph



Observation

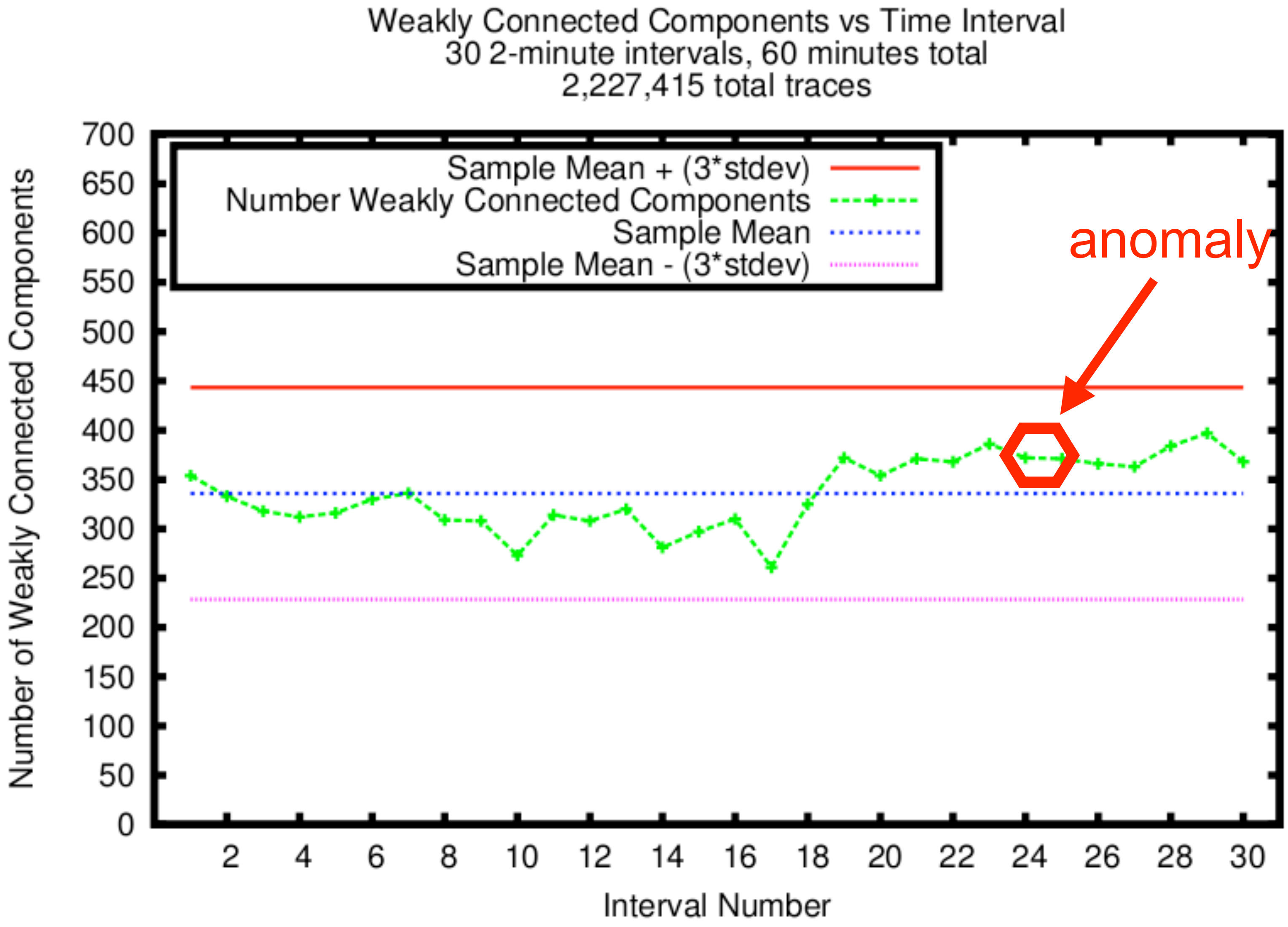


Observation



Diameter vs Time Interval
30 2-minute intervals, 60 minutes total
2,227,415 total traces

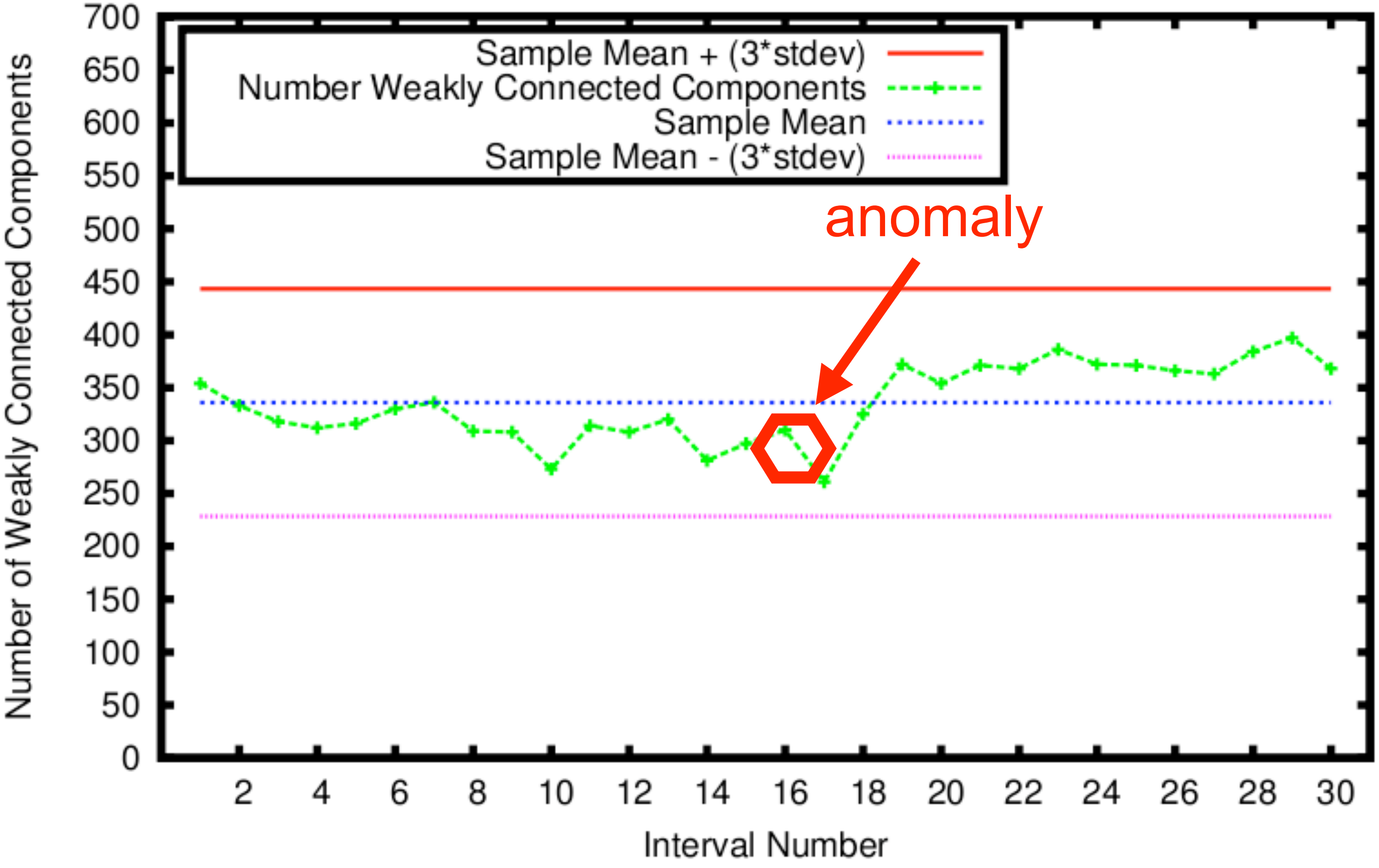
Observation



anomaly

Observation

Weakly Connected Components vs Time Interval
30 2-minute intervals, 60 minutes total
2,227,415 total traces



anomaly

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- Danger of hypersensitivity, over-fitting
  - A vulnerability

Ideas Generated

- Inject synthetic anomaly data into otherwise normal data-set
  - Independently developed, shared data-sets

Thank you.