High-Throughput Real-Time Network Flow Visualization

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Tools and a Pipeline to Provide Defense in Depth

- **Traffic Circle**
  - Visualization for situational awareness

- **Correlation Layers for Information Query and Exploration (CLIQUE)**
  - Network behavior visualization using LiveRac interface

- **Middleware for Data-Intensive Computing (MeDiCi)**
  - Data pipeline
Motivation

- Improve upon current analysis capabilities
  - Provide a mechanism for multiple tools to feed off the same data
  - Move away from batch processing of flow data
  - Support both forensic and real-time monitoring capabilities

- Implement a streaming analytics tool set
  - Handle large volumes of flow data (millions to billions) per view
  - Help analysts gain situational understanding of current state of a network

- Provide engaging flow visualizations
  - Visualization of both raw data and aggregates
  - Automated identification of off normal conditions
What our users want

They want to know what normal looks like – from an individual host, to a group, to an enterprise

They want ways to overcome limitations in analyzing raw transactions

- Lots of data (billions of transactions/day)
- Lots of unique actors (IPv6: $6.67 \times 10^{27}$ IP addresses per square meter on Earth)
- Lots of noise

If they know what they’re looking for, they can build a signature to detect it. **But what’s in the data that they don’t already know to look for?**

- Need to link data reduction techniques with exploratory analysis interfaces

They want to know where to focus!
Middleware for Data-Intensive Computing (MeDICi)

- Provides a high-throughput data communication and processing pipeline
  - Creates the substrate for real-time information sharing

- Mechanism to hand information to multiple tools
  - Multiple tools “subscribe” to MeDICi data, so that tools can be combined for defense in depth

- Capable of streaming data transformations
  - Handles data changes needed by a client prior to being transmitted to that client
    - Offloads computational cycles to the MeDICi server
Using MeDICi for real-time analytics

- Components can be created by different developers using various languages
  - Traffic Circle and CLIQUE use Java, but components from other languages can be wrapped easily

- Information is passed between components using a producer / listener mechanism
  - Apache ActiveMQ message broker
  - JMS messaging standard

- Components are chained together to create a pipeline
  - Aggregates
  - Summary Statistics
  - Others
A sample MeDICi pipeline
CLIQUE

- Produces behavioral summaries based on a live sensor feed

  - A behavior is a model of predicted activity based on past activity
  - CLIQUE helps visualize the deviation of an actor from its predicted activity
  - Working at the level of behaviors helps cope with large data volumes
  - Display “walks” along with incoming flow information to show current state

- Helps highlight trends and patterns in high-volume flows

  - Capability to compare behavior deviations with category activity
CLIQUE behavior analysis

- Utilizes Symbolic Aggregate approXimation (SAX)
  - To deal with the scaling issue in the temporal dimension (scales by summarization/aggregation)
- Creates a SAX representation across all categories for a given actor
- Converts SAX representation to a glyph
  - Produces a language
- Creates matrix of glyphs and temporal sub-segments
- Compares current matrix and historic matrix to yield behavior deviation plot
CLIQUE Walkthrough
Traffic Circle

- Interactive visualization of patterns in high volume flow data
  - When you can see more data you can see patterns previously hidden when examining by subsets

- Visualizes raw flow information
  - Drill-through from CLIQUE
  - Manages throughput by utilizing a threaded architecture that distributes query and rendering

- Can operate in forensic mode or real-time animation mode
Traffic Circle

- Circular “time wheel” metaphor
  - Flows ordered by start time
  - Arc length corresponds to duration
  - Spinnable interface

- Filters can be added
  - Color coding
  - Hide / show capability

- Operationally demonstrated at data volumes upward of 125 million flows
  - Using high-performance backfill database
Traffic Circle Walkthrough
Conclusions

- Visualization at different levels of abstraction supports situational awareness in large data sets
- High-throughput pipelines are necessary to scale visual analysis to operational data volumes
- Modeling helps analysts baseline normal activities and quickly identify off-normal conditions
Future Directions

▶ Develop a predictive capability
  - Nascent behavioral changes can be detected visually in real-time in Traffic Circle and CLIQUE
  - CLIQUE classifier enables **sequence detection** for proactive threat identification

▶ Explore extensions to other domains
  - Financial fraud detection
  - SCADA system reliability and security