Atypical Behavior Identification in Large Scale Network Traffic

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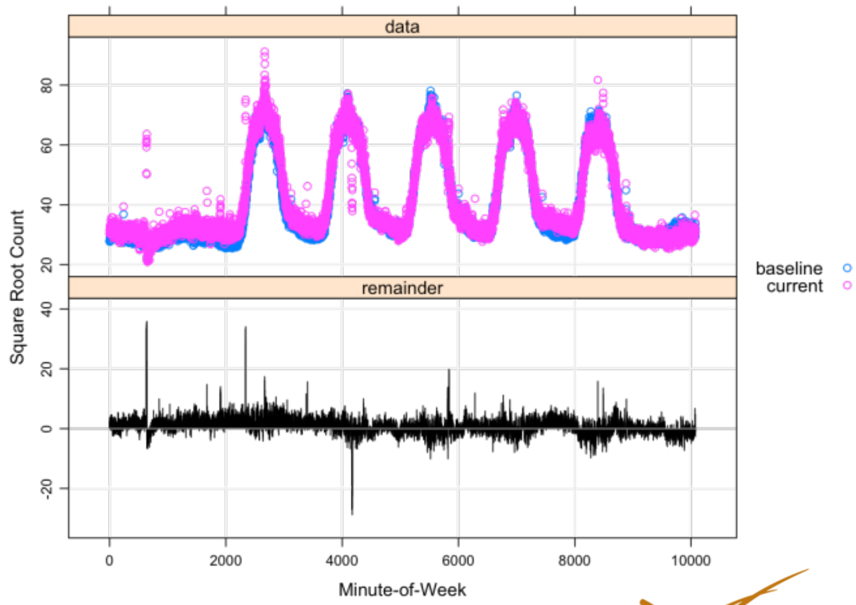
Agenda

- Background
- Behavioral algorithm
- Scalable data intensive architectures
- Visualization
- Future directions



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What is large scale network traffic?

- Most enterprises use some kind of **continuous traffic monitoring**.
  - Captured in either pcap or network flow format
- Network flow is a summarization of network communication
- Network flow is **ubiquitous and voluminous**
  - Groups of computers can easily have thousands of flow records per second
  - Large enterprises generate billions to tens of billions of flow records per day
- src: 192.168.24.244, dest:123.321.184.1, src-port:62826, dest-port: 80, proto: 6, start-dtm: 1131850246948, end-dtm:1131850247948, duration: 235, packet-cnt: 38, byte-cnt: 11383, initial-flg: 2, all-flg: 27

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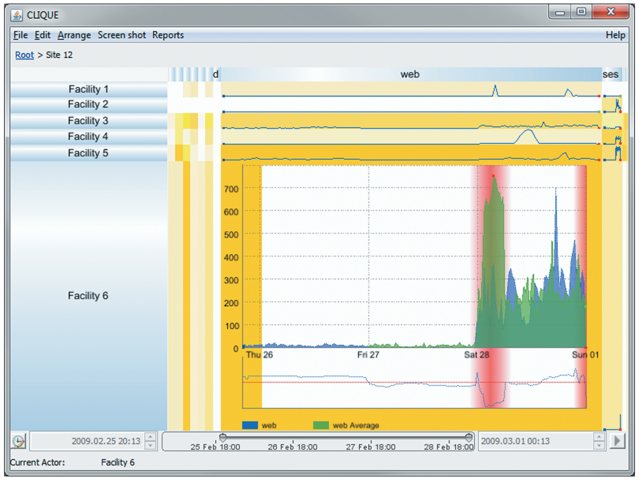
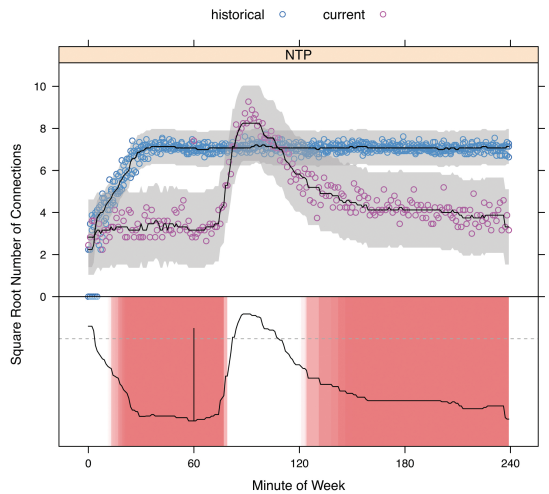
Development goals

- Provide situation awareness and event discovery in large data sets
- Facilitate behavioral modeling and anomaly visualization for streaming network traffic
- Be capable of real-time and exploratory mode of investigation





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How to find atypical behavior?

- Application concepts paying attention to three areas
  - **Algorithm**: Must be efficient to cope with volume of data
  - **Data Management**: Must be able supply data quickly
  - **Visualization**: Must provide the user the ability to discern atypical behavior and begin investigation process
- Meeting our goals
  - Operationally demonstrated on a dataset containing 100B flow records
  - Demonstrated capability to stream network flows at ~3 thousand flows per second on a single desktop computer

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Atypical behavior algorithm background

- Behavioral model based on temporal patterns
  - Improvement over previous models (SAX: Symbolic Aggregate approXimation)
- Operates under the assumption that network flow attributes exhibit cyclical behavior of a weekly periodicity
  - Exploration has shown this holds well for most protocols
- Various attributes can be modeled
  - Total bytes, total packets, network flow count
- Aggregation is necessary for statistical robustness

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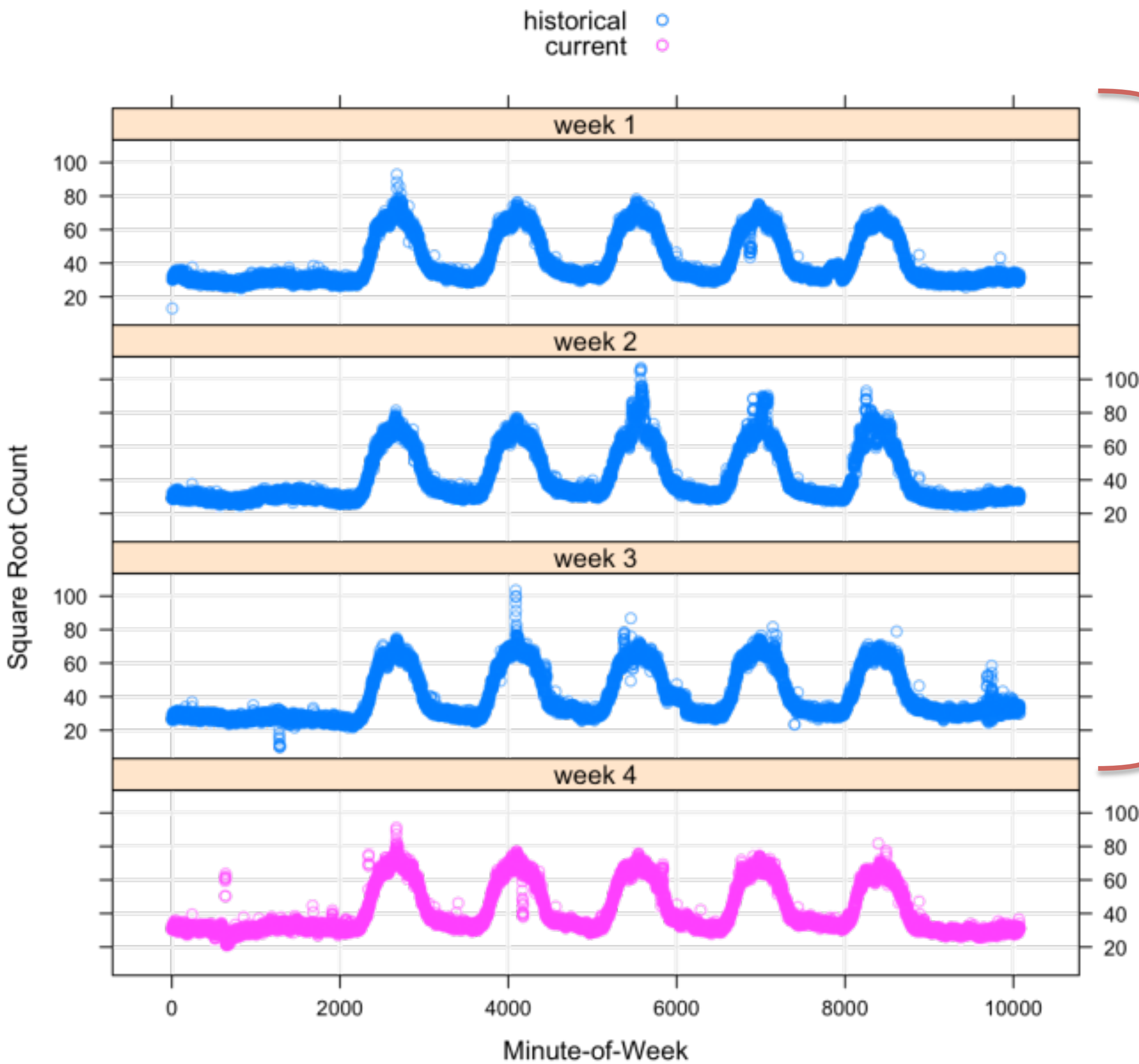
Weekly periodicity



Take median to form baseline

Comparing current activity to historical trends

- Running median calculated for single current series and for m number of historic series

$$c_t = \text{median}\left(x_j : j \in \left(t - \frac{k-1}{2}, \ldots, t + \frac{k-1}{2}\right)\right) \quad h_t = \text{median}\left(x_j^{(i)} : i \in (1, \ldots, m), j \in \left(t - \frac{k-1}{2}, \ldots, t + \frac{k-1}{2}\right)\right)$$

- Median absolute deviation (MAD) calculated based on current and historic running medians

$$\hat{\sigma}_c = K \text{ median}(|x_t - c_t| : t \in (1, \ldots, n)) \qquad \hat{\sigma}_h = K \text{ median}(|x_t^{(i)} - h_t| : i \in (1, \ldots, m), t \in (1, \ldots, n))$$

- MAD and a configurable deviation number used to set upper and lower bounds for current and historic series

$$c_t^{lower} = c_t - \alpha\hat{\sigma}_c \qquad h_t^{lower} = h_t - \alpha\hat{\sigma}_h$$
$$c_t^{upper} = c_t + \alpha\hat{\sigma}_c. \qquad h_t^{upper} = h_t + \alpha\hat{\sigma}_h$$

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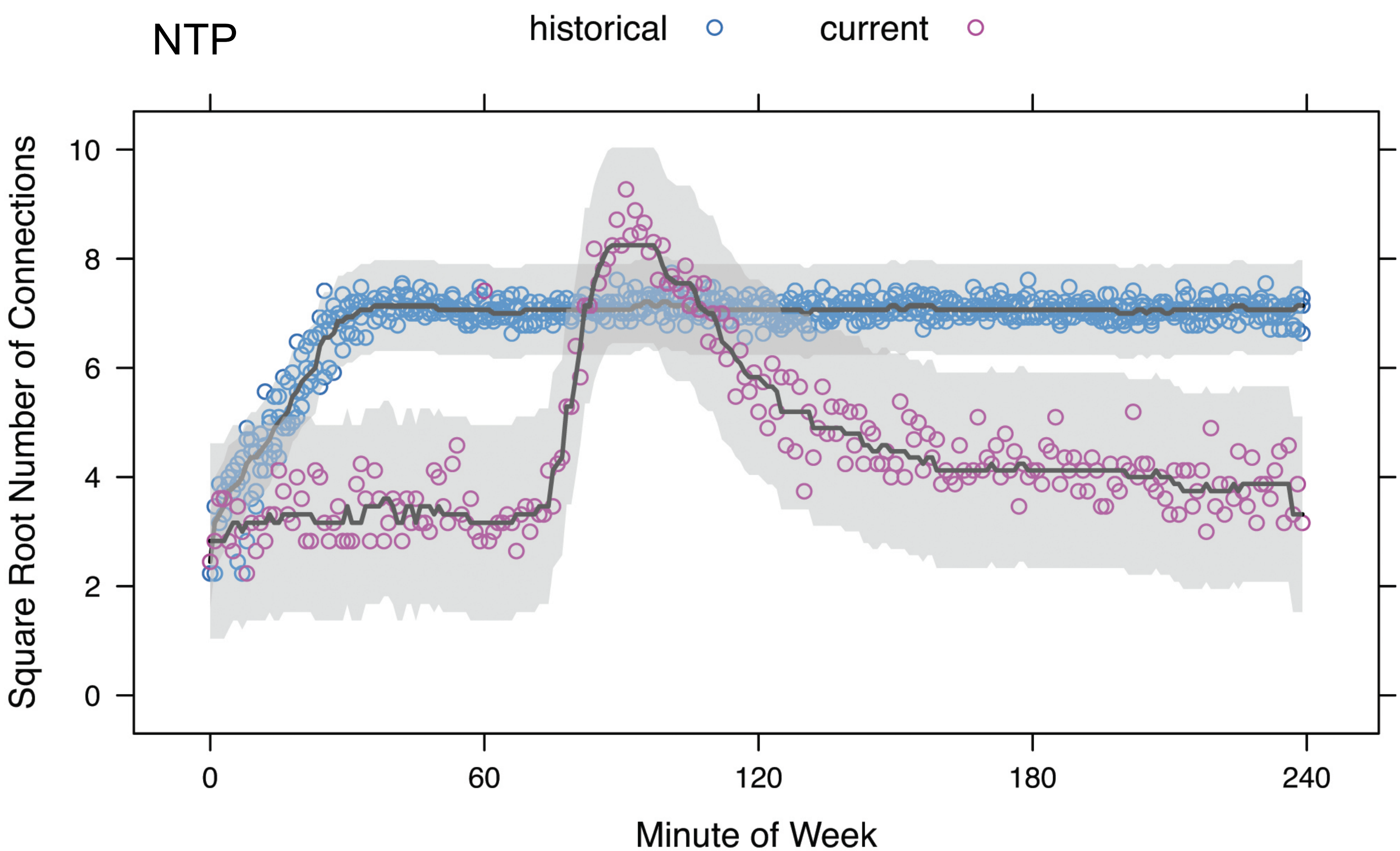
Current and historic trend overlap



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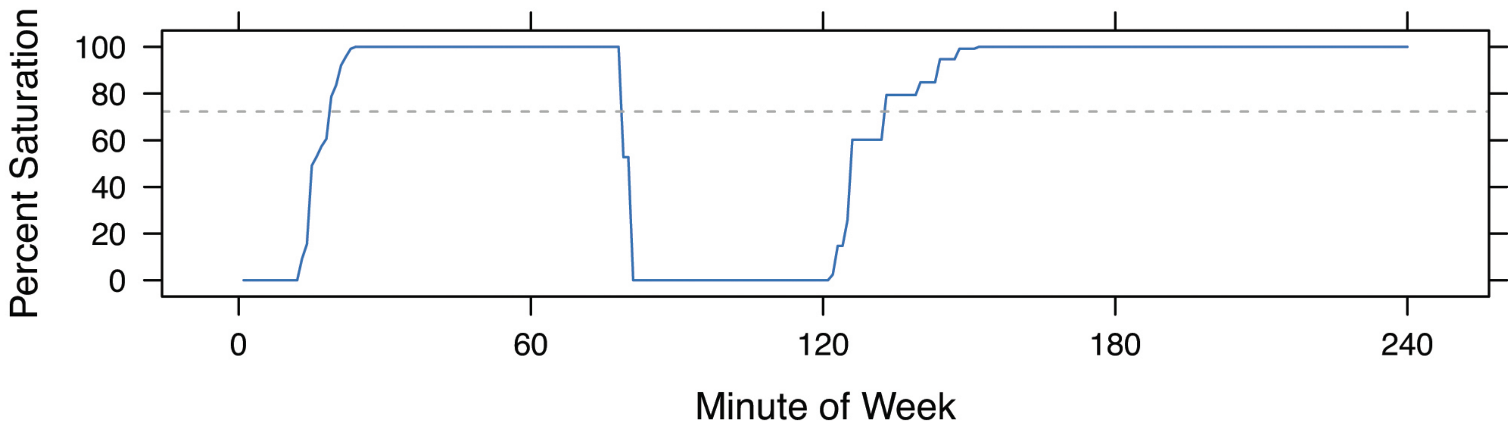
Visually encoding overlap with saturation

$$\lambda_t = \begin{cases} \max(0, c_t^{upper} - h_t^{lower}) & h_t > c_t \\ \max(0, h_t^{upper} - c_t^{lower}) & h_t <= c_t \end{cases}$$

$$s_t = \begin{cases} 0 & h_t = c_t \\ 1 - \min(1, \lambda_t / |\delta_t|) & h_t \neq c_t \end{cases}$$

Saturation used to color encode the background of plots



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Scalable data intensive architectures

- Client visualization with various database back-ends
  - Postgres, Greenplum, Netezza
  - Needs database driver and appropriate configuration files
- Scalability through aggregation
  - Using summary table (not required), improves performance
- Network traffic grouped into categories
  - Rule based categorization algorithm
  - Based on attributes available in the data
    - port, protocol, payload, etc.

Primary data architecture focus

- Development and research on Netezza
  - Leverages available hardware and closely resembles the target release architecture
  - We still remain database agnostic for other deployments
- DISTRIBUTE ON Clause
  - Determines how data is distributed across database appliance (Netezza specific)
  - Candidate keys should have high cardinality and commonly used in joins
  - We chose IP address

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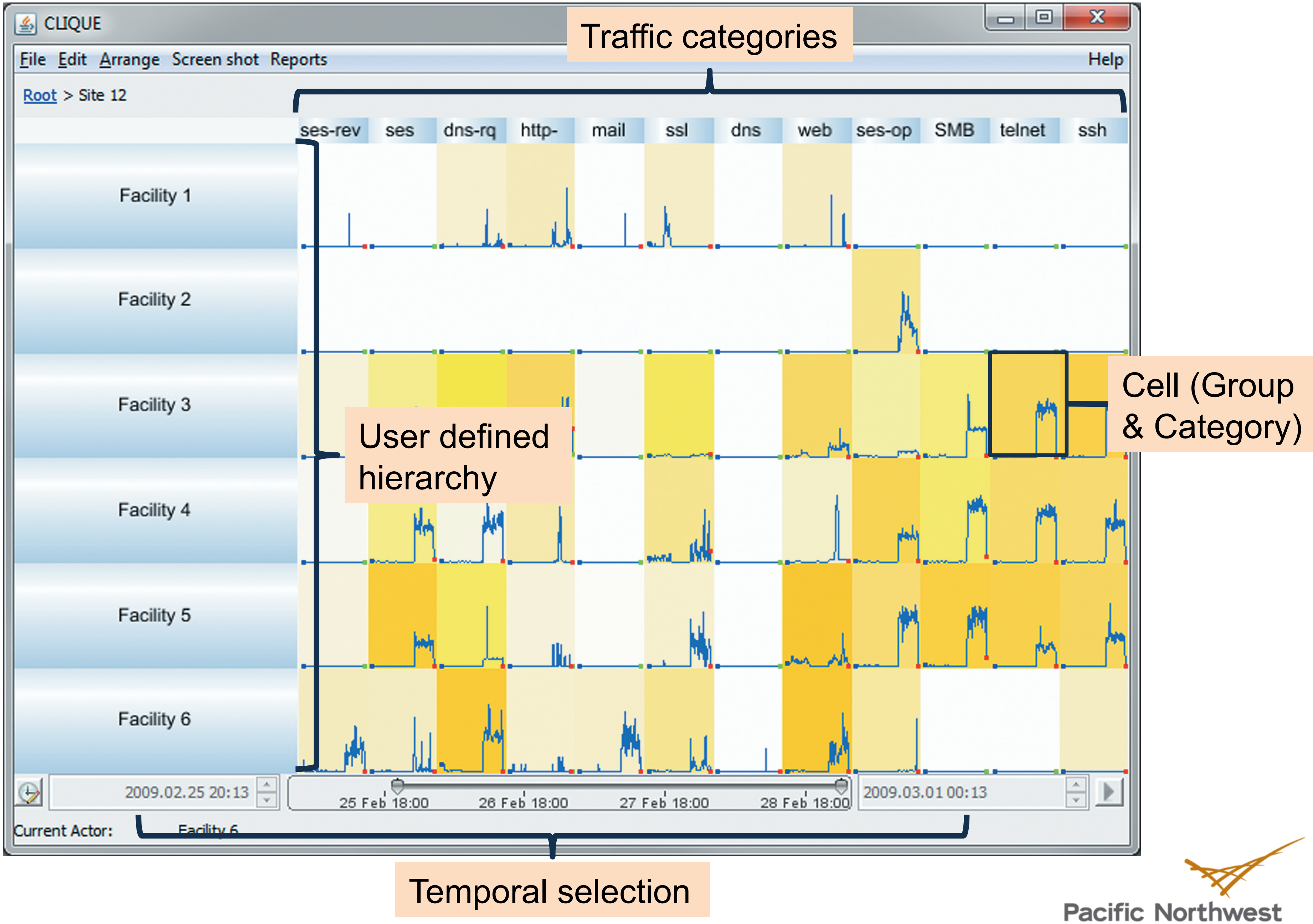
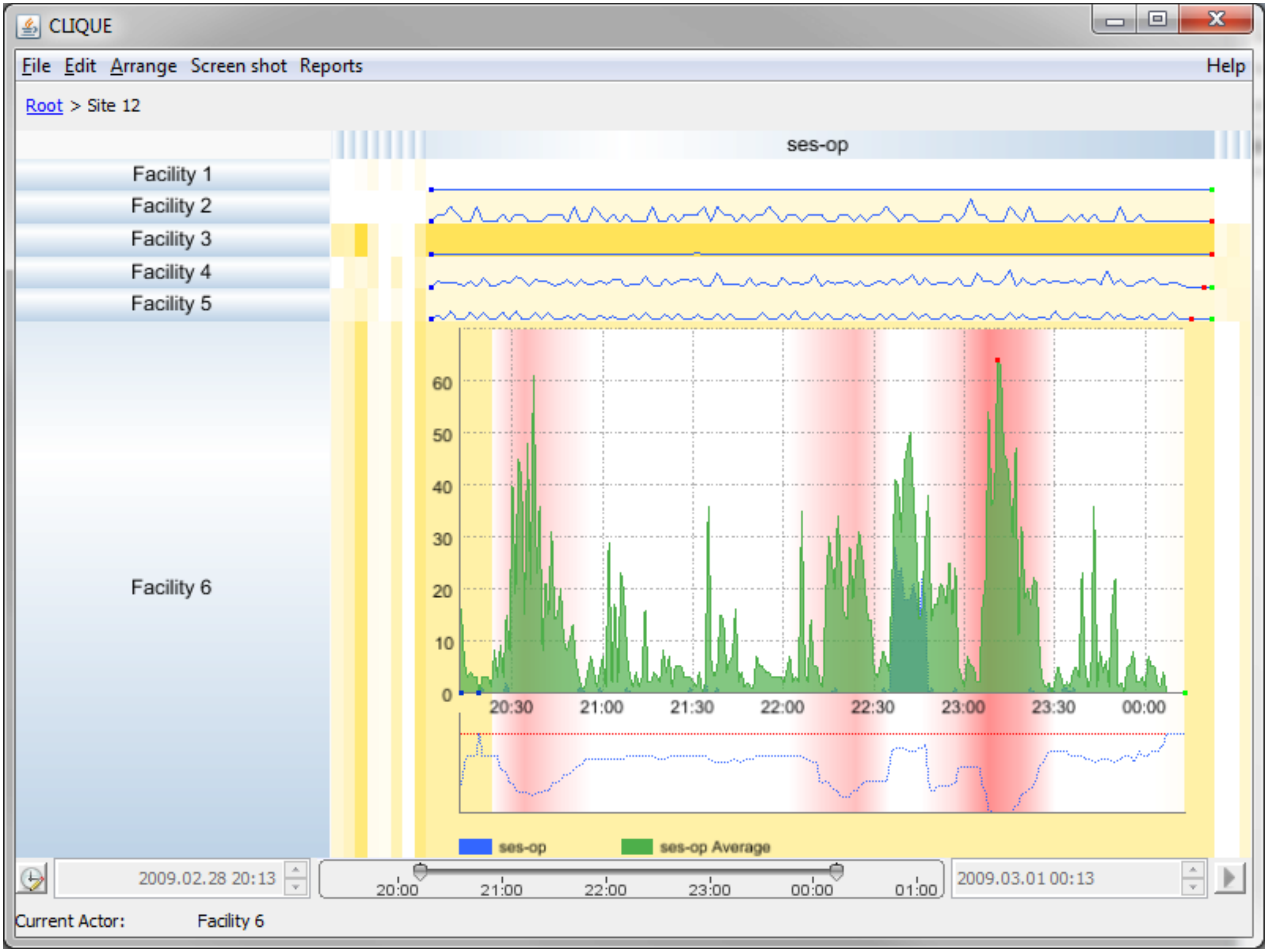
Atypical behavior visualization (Clique)

- Behavior baseline for actors
  - Creates statistical model of what is typical for a given actor and category set
  - Visualizes the deviation from typical activity
- Actor / group hierarchy
  - Groups of IP addresses, a single IP address, or query based on an attribute
    - Site > Facilities > Buildings > Individuals
  - Individually configurable and sharable
- Interactive interface provides semantic zooming (LiveRac)
  - Added adaptive bin widths, deviation highlighting, stability, and database independence


CLIQUE
File Edit Arrange Screen shot Reports
Help
Root > Site 12
Traffic categories
ses-rev
ses
dns-rq
http-
mail
ssl
dns
web
ses-op
SMB
telnet
ssh
Facility 1
Facility 2
Facility 3
Facility 4
Facility 5
Facility 6
User defined hierarchy
Cell (Group & Category)
2009.02.25 20:13
25 Feb 18:00
26 Feb 18:00
27 Feb 18:00
28 Feb 18:00
2009.03.01 00:13
Current Actor:
Facility 6
Temporal selection



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Future directions

- Investigate and implement alternative bottom up approach
  - statistical model per IP address and aggregation based on that model
- Improve interface performance
  - Investigate alternate middle tier architectures
- Enhance applicability by developing prototypes in different domains
- Incorporate abrupt outlier identification and visualization

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How to get in touch

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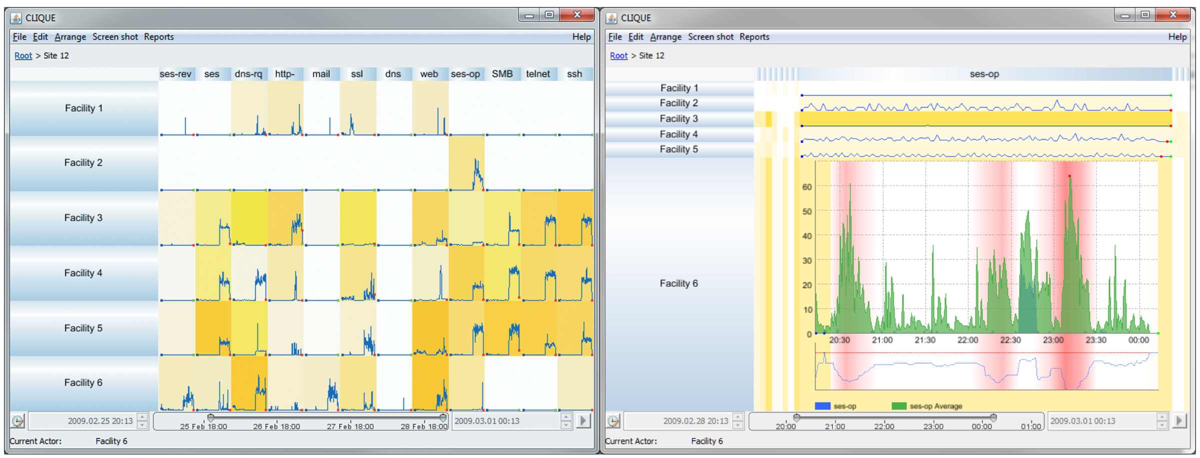

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