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Combating Dependence Explosion in Forensic Analysis Using Alternative Tag Propagation Semantics

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Drawbacks of Existing Approaches

- "Needle in a haystack:" Hard to distinguish real attacks within a flood of false alarms
- "Connecting the dots:" No help in understanding the overall campaign
  - Solution: Use *provenance* information
  - *Issue: Dependency Explosion*

Our Approach

- Policy-based attack detection and root cause identification
- Modulate dependency flow using subject tags
- *Conservative* dependence propagation for *suspicious* processes
- *Selective* dependence propagation for benign processes,

Scenario Graph Generation

Provenance-based alarm clustering: Attribute an alarm to an ancestor that also triggered alarms.

Entry point identification: Trace back from largest clusters to a source node (e.g., network connection).

Re-propagating tags: Assign suspicious Subject tag to entry point, repropagate tags as needed.

Forward search: Run depth-first search and prune away nodes with high data integrity

Local simplifications and visualization

Subject & Data Tags

Subject Tag

Suspicious: Process may have been compromised.

Benign: Believed to be benign; may contain vulnerabilities.

(Data) Integrity Tag

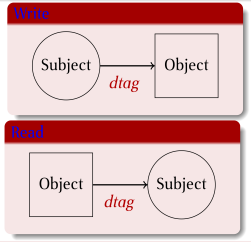
- Low: $[0.0, 0.5)$
- High: $[0.5, 1.0]$

(Data) Confidentiality Tag

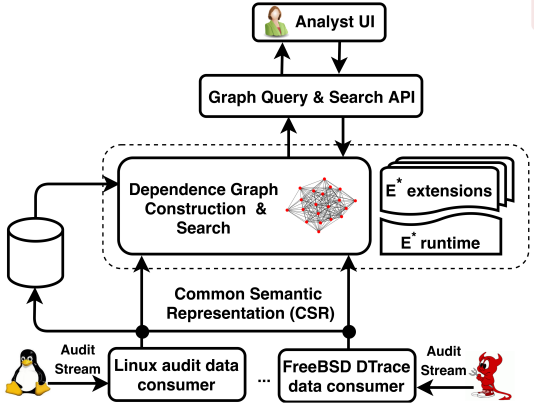
- High: $[0.0, 0.5)$
- Low: $[0.5, 1.0]$

Default Tag Propagation

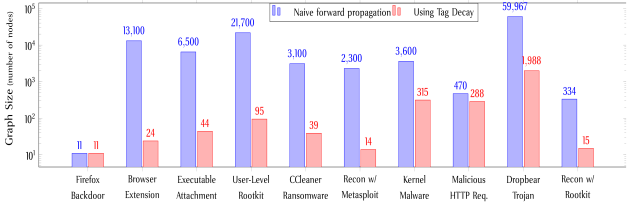
Normally, tags propagate in the direction of *information flow*



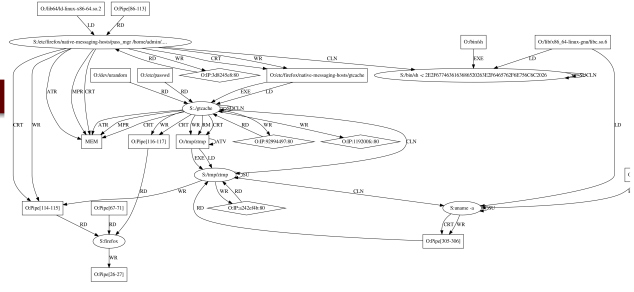
Default propagation causes *dependence explosion*, which leads to *massive (unreadable) scenario graphs*



Graph Size Reduction



Scenario Graph for Vulnerable Browser Extension



Tag Attenuation

- Key intuition: *Objects* are lousy intermediaries for propagating attacks
- Key Idea: *Attenuate* tag propagation from *benign* subjects to objects
- Implemented by adding a small constant a to data tag value:

$$object.dtag = subject.dtag + a$$

Tag Decay

- Key intuition: If a benign process is compromised by suspicious input, this will happen soon after consuming it
- Key Idea: *Gradually lift* tags of *benign* processes to *quiescent* value T_q
- By decaying data tag d exponentially at rate r

$$d = max(d_0,\ d_0 * r^t + (1 - r^t) * T_q)$$

Performance

Data set	Total events	Memory Usage (GB)	Graph generation time/attack (sec.)
L3	714 M	0.49	0.043
L4	36.5 M	0.11	0.053
F3	21 M	0.19	0.030
F4	37.2 M	0.11	0.220