Take Only What You Need: Leveraging Mandatory Access Control Policy to Reduce Provenance Storage Costs

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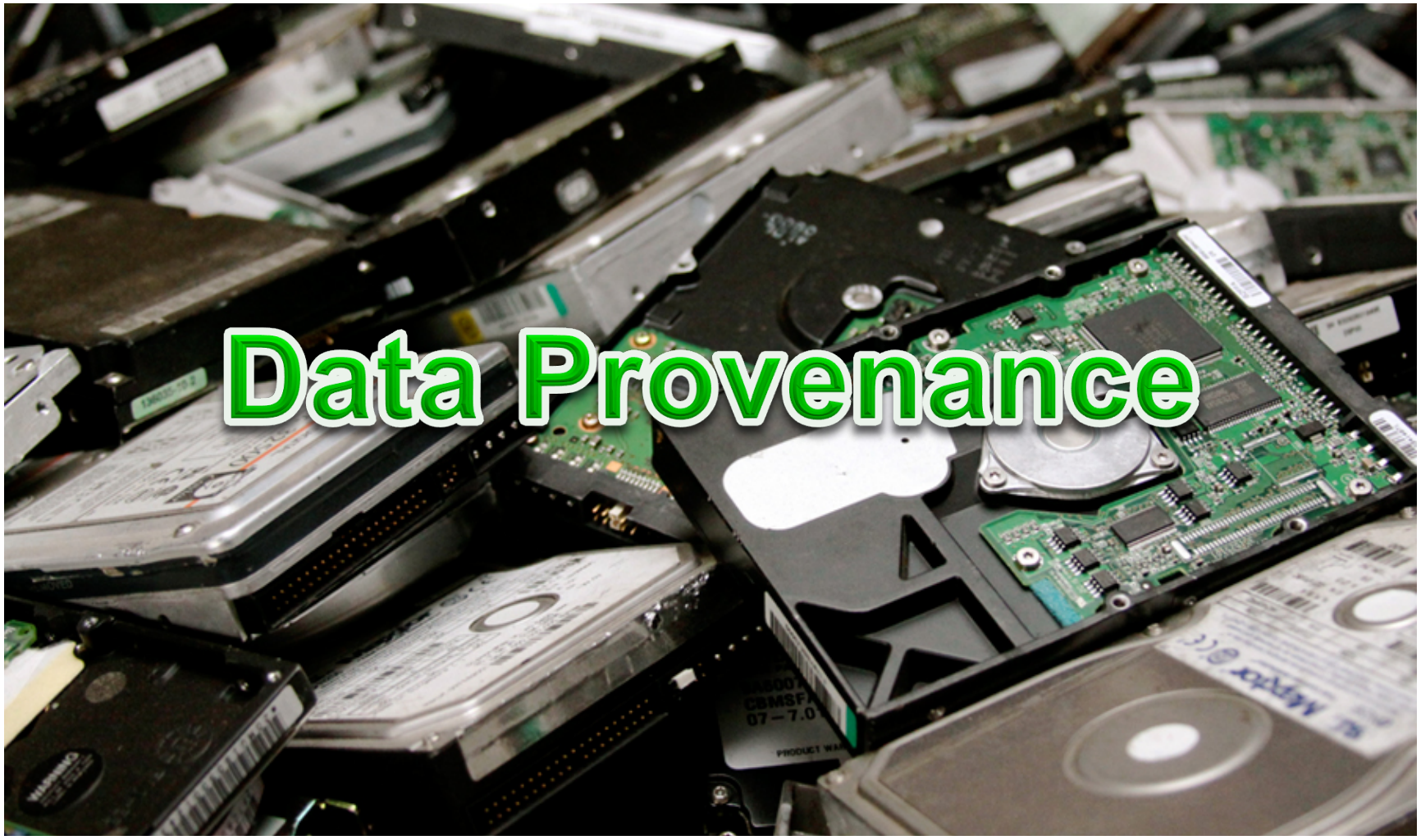
TaPP '15, Edinburgh, Scotland

9th July, 2015

This work is sponsored by Assistant Secretary of Defense for Research and Engineering under Air Force Contract FA8721-05-C-0002. Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the United States Government.

Deal-breaker for system provenance?



Provenance-Aware Adversaries

The environment we consider in this work is *not* benign.

Active provenance-aware adversaries attempt to:

- Evade monitoring
- Tamper with prov. logs
- Disable prov. mechanisms

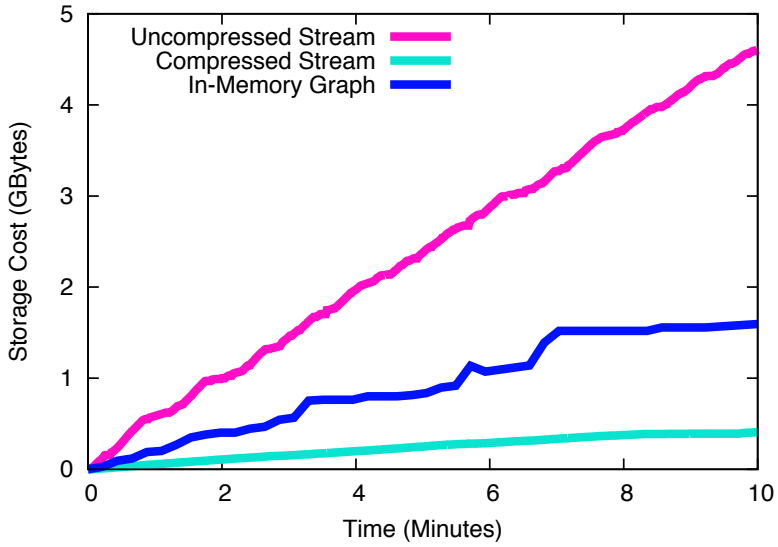
Provenance Monitors:

- Record complete, gapless provenance
- Tamperproof
- Verifiably correct

Deal-breaker for system provenance?

High storage overheads for system layer provenance collection:

- Provenance-aware systems generate GB of metadata on the order of minutes.
- Hi-Fi module generates 4.8 GB during kernel compile.
- After processing, PASS reports similar overheads (~1.5 GB).

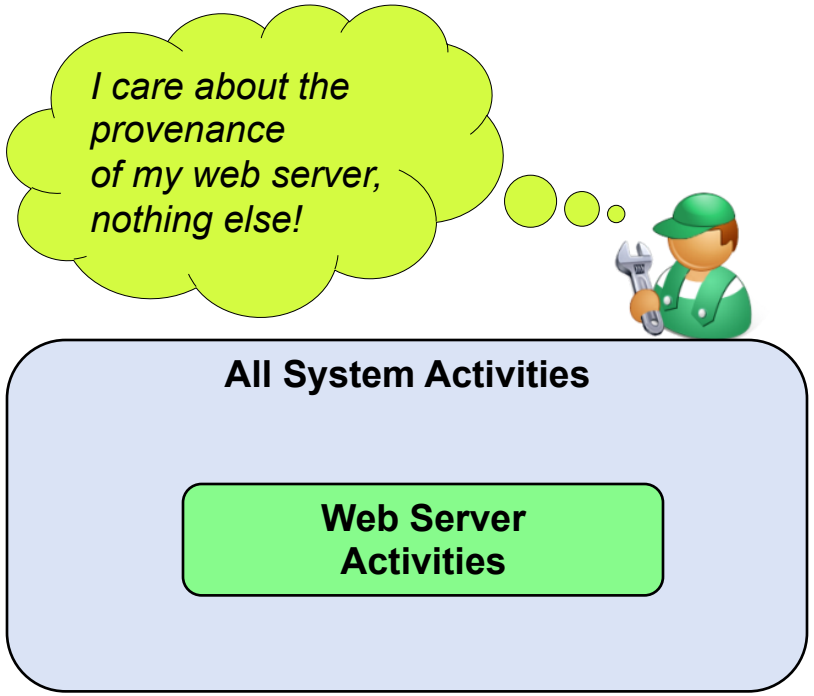


Kernel Compilation benchmark for Hi-Fi using different storage techniques

Deal-breaker for system provenance?

High storage overheads for system layer provenance collection:

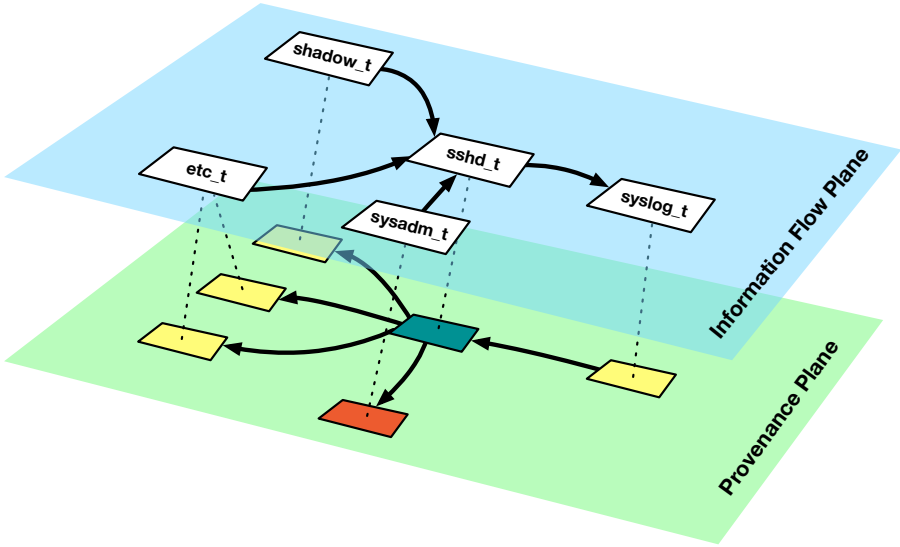
- Worse, a percentage of that provenance is *uninteresting.*
- Provenance compression techniques cannot remove uninteresting data.
- In Discretionary Access Control systems, we cannot guarantee *completeness* without recording *everything*.



“Provenance Walls”

We propose that Mandatory Access Control (MAC) systems can facilitate the performance of selective provenance collection.

- Background
  - Threat Model
  - Storage Overheads
- **Provenance Walls**
  - Provenance & MAC
  - Policy Analysis
- **Future Work**
  - Design & Implementation
  - Challenges
- **Conclusion**



Provenance Walls integrates Provenance with Mandatory Access Control policy.

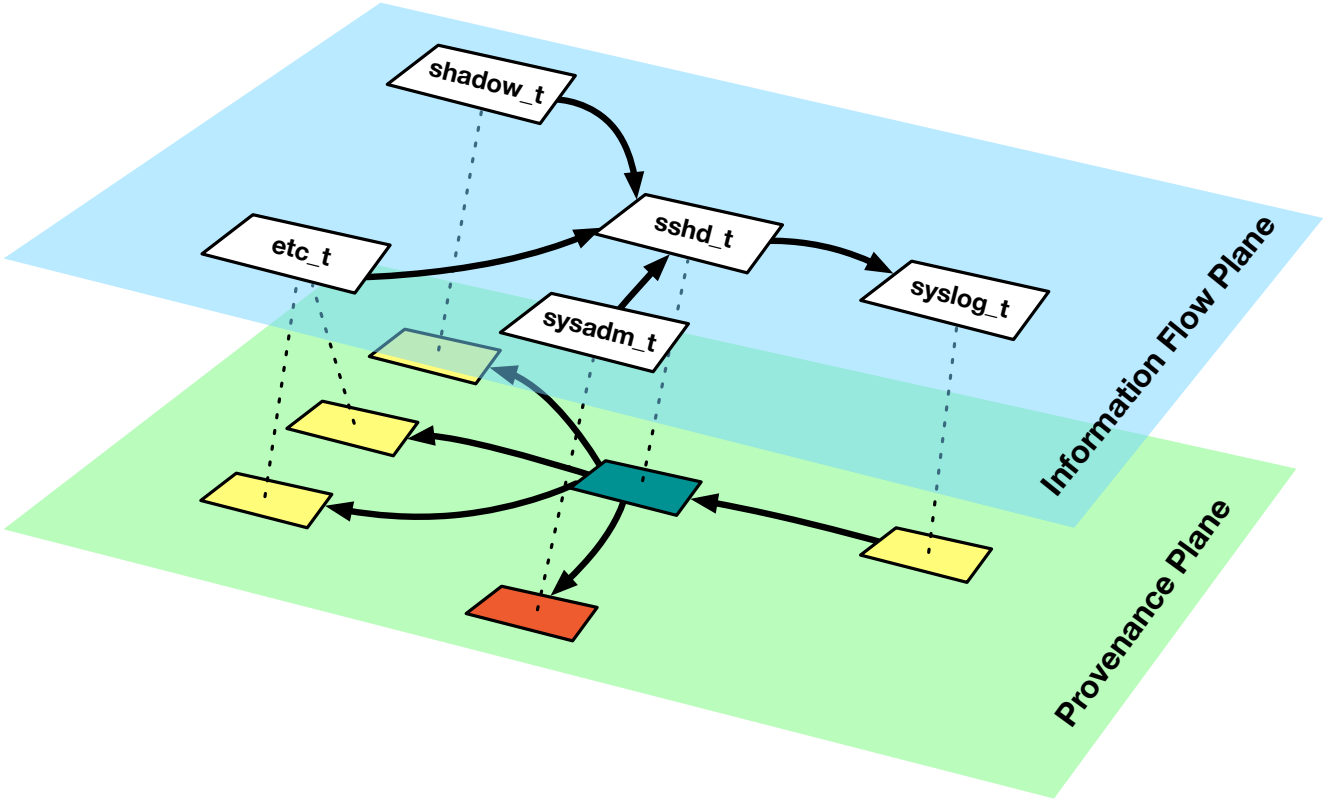
Provenance and Mandatory Access Control

What is the relationship between Provenance and MAC policy?

- **With MAC, we can reason about where data will (not) flow.**
  - MAC answers questions about **possible** future events
- **With Prov., we can reason about where data did (not) flow.**
  - Provenance answers questions about **actual** past events
- **MAC systems assign a security label to every system object.**
  - Objects in MAC namespace map to objects in provenance namespace.

Provenance and Mandatory Access Control

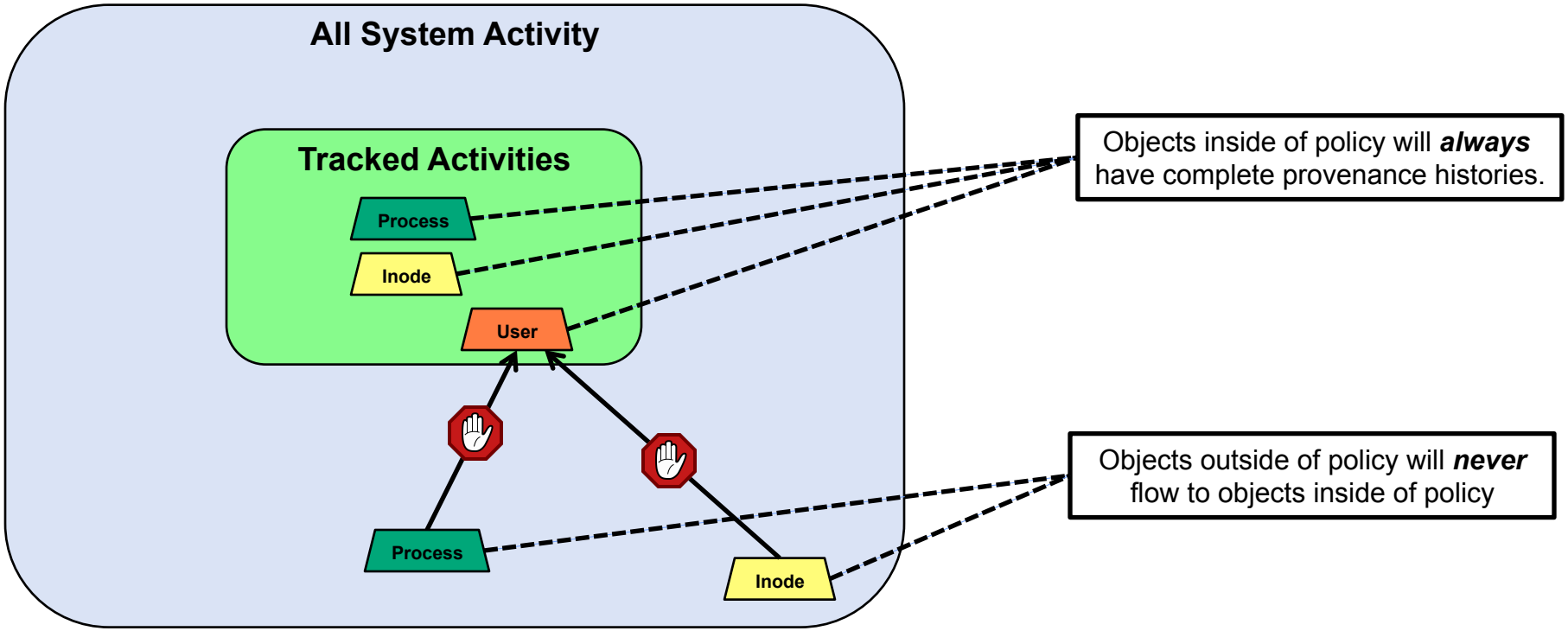
We could define a *provenance policy* in terms of security labels…



… but where does that leave us in terms of assuring *completeness?*

Selective Completeness

Definition: *A provenance sub graph that is complete in its description of a specified system activity… in perpetuity!*



Policy Analysis

Integrity Walls [Vijayakumar et al. 2012]:

- MAC policy analysis tool that identifies an application's attack surfaces.
- Static analysis identifies *executable writers*, *kernel subjects*, and *helper subjects* that form **Minimum Trusted Computing Base (MTCB)**:

```
http_t, http_config_t,
http_user_content_t,
lib_t, http_packet_t
```

- Dynamic analysis is then used to identify adversary-controlled entry points:

```
http_user_content_t,
http_packet_t
```

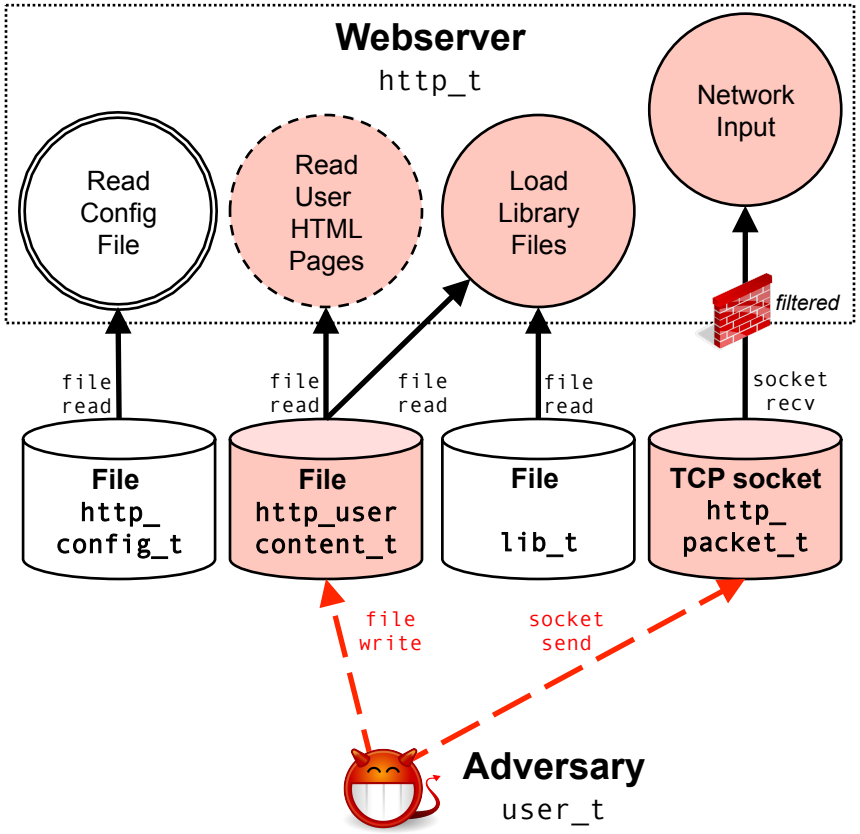


Figure adapted from [Vijayakumar et al. 2012]

Policy Analysis

Integrity Walls [Vijayakumar et al. 2012]:

- Adapt the static analysis tool to create a provenance policy:
- For a given application s, divide the policy P into a set of trusted labels I_s and an untrusted set O_s.
- I_s exhaustively describes the objects that can flow into s.
- I_s is a provenance policy that is *selectively complete* for s.

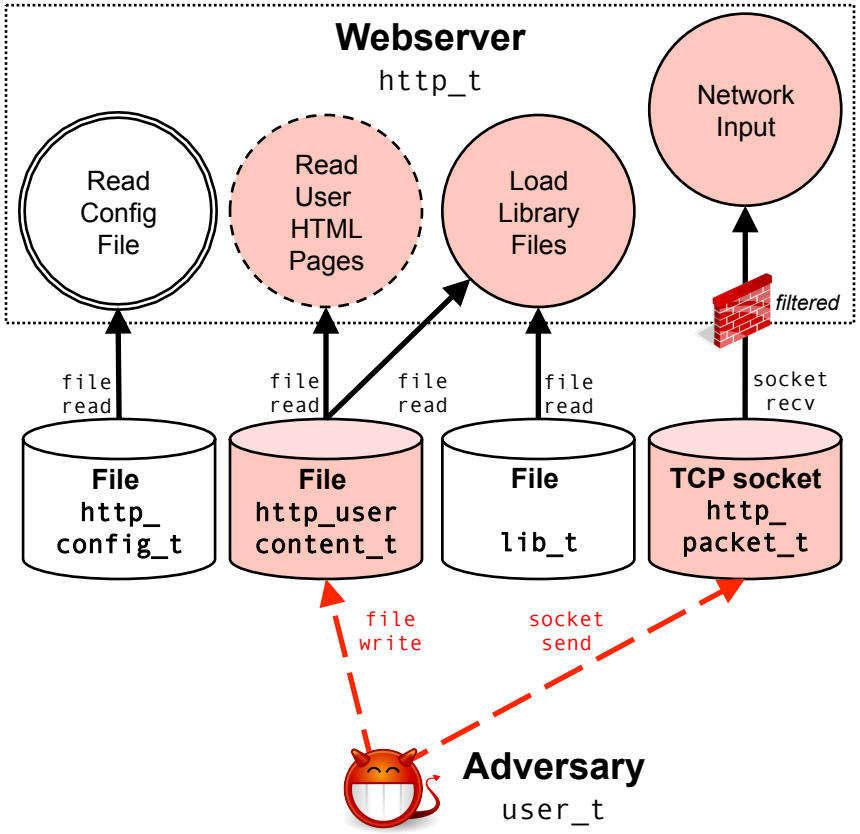


Figure adapted from [Vijayakumar et al. 2012]

“Provenance Walls”

We propose that Mandatory Access Control (MAC) systems can be leveraged to perform policy-based provenance collection.

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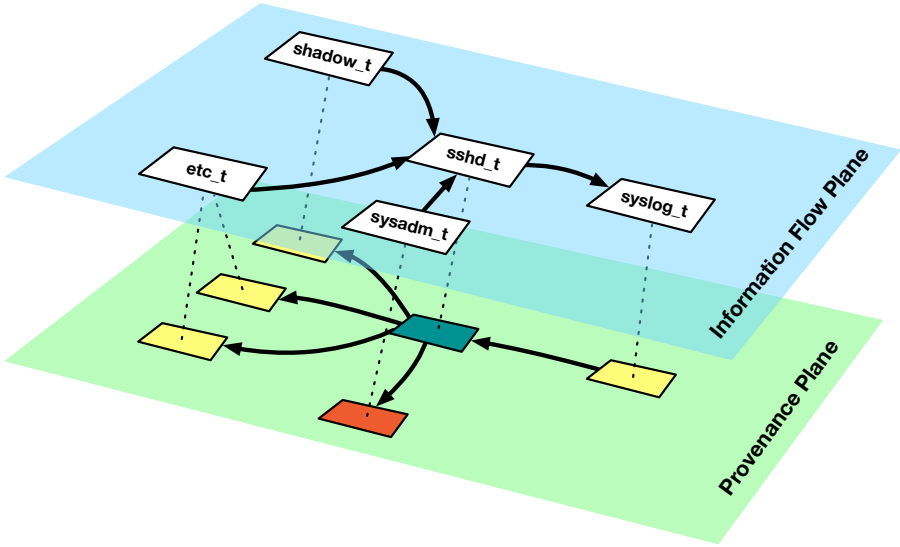

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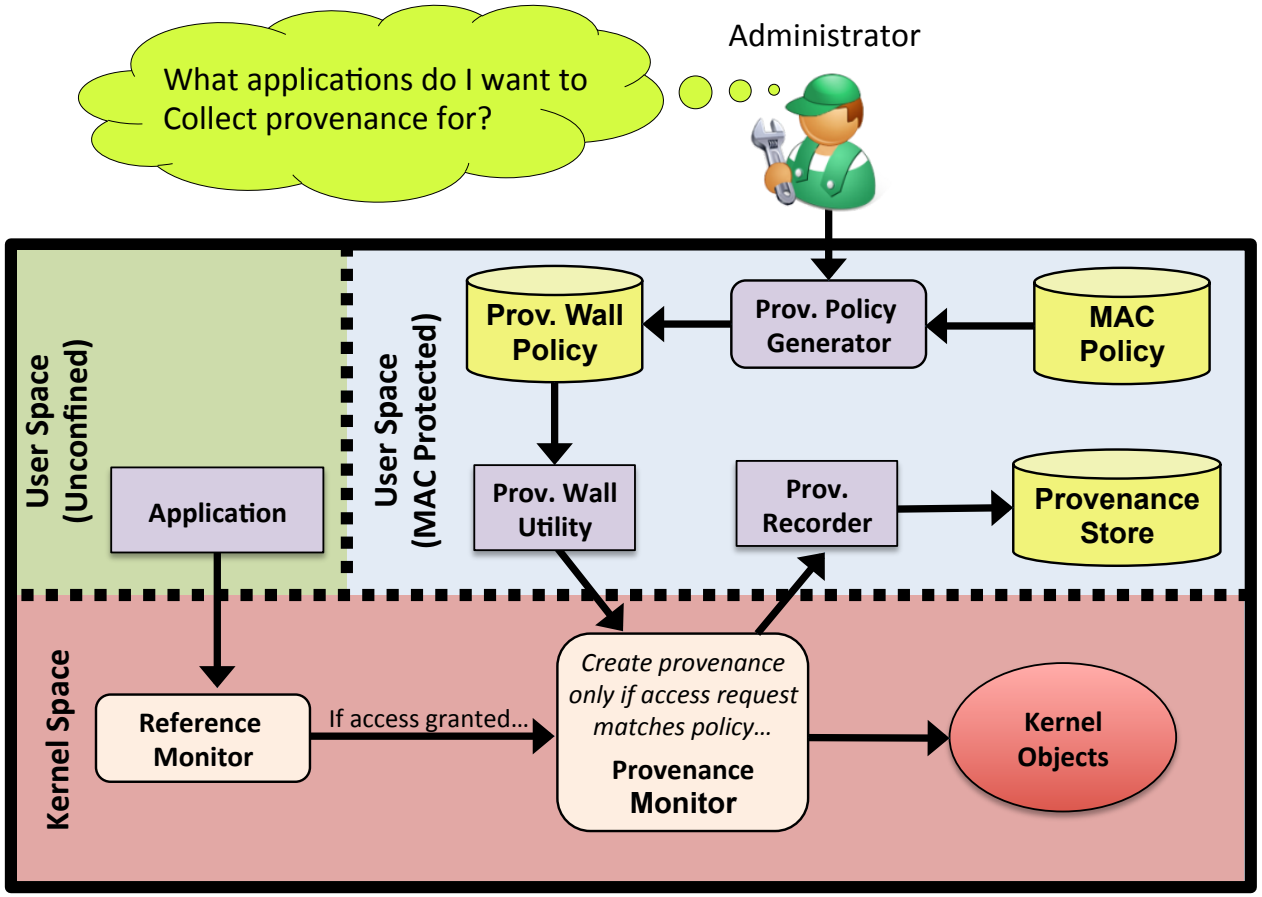
Provenance Walls Architecture

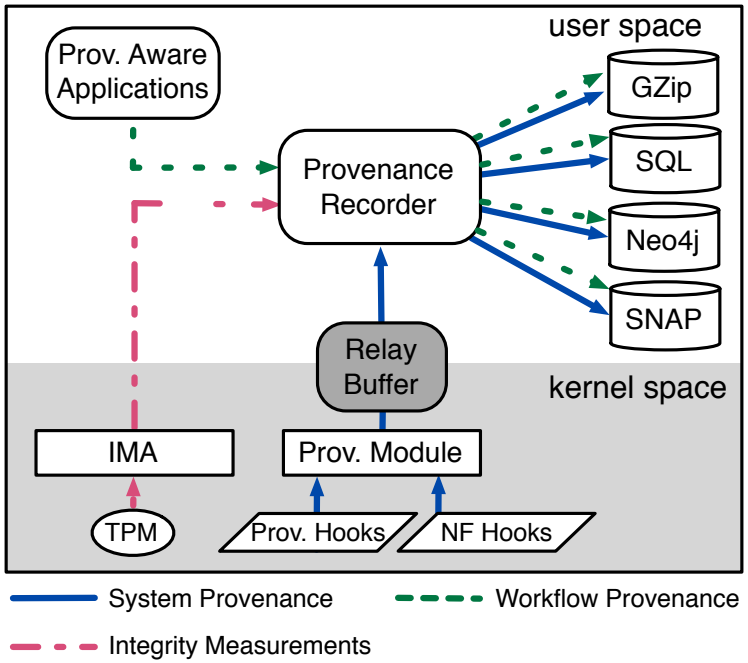
Our architecture for selective provenance recording is shown below:



Linux Provenance Modules

We are developing Provenance Walls using the Linux Provenance Modules (LPM) Framework [Bates et al. 2015]:

- Satisfies “Provenance Monitor Concept”.
- Provenance hooks permit observation of all kernel objects
- Can be simultaneously enabled with SELinux
- We will create a policy-aware version of LPM’s Hi-Fi module [Pohly et al. 2012].



Linux Provenance Modules Architecture

(Highly Contrived) Evaluation

- We made minimal modifications to Hi-Fi to access SELinux security contexts and perform a single policy check.
- **Our Policy:** *"I am not interested in things that happen in user's home directories (*`user_t`*)!!"*
- We then performed kernel compilation test in our home directory:

Module	Provenance Size
Hi-Fi	54 MB
Policy-Aware Hi-Fi	10 MB

Note: Provenance logs are compressed with gzip here.

- **Takeaway:** Savings are domain-specific, and dependent on how many system activities can be pruned.

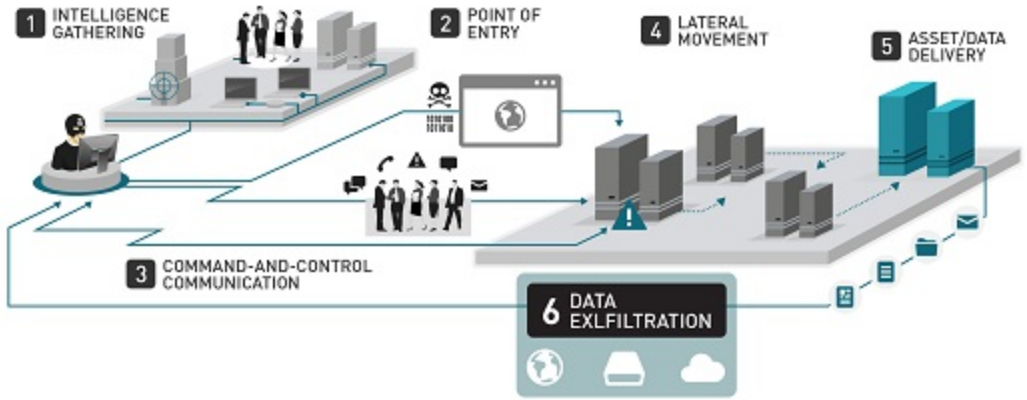
Challenges

- **Policy-Aware Provenance gives rise to new kinds of provenance queries, including:**
  - ***Why is this subgraph missing*?**
    - *Proof that graph omissions are due to correct policy decisions, not error.*
  - ***Where can this data go?***
    - *When reasoning about data provenance, use MAC policy to "look into the future" of system execution.*
  - ***What other data objects are similar to this data object?***
    - *Leverage MAC policy to identify related items by security label*
    - *Objects that are related according to MAC policy may appear unrelated in the provenance graph.*

Challenges

Develop other algorithms for selectively complete policies

- **"Provenance Walls" is great for monitoring a specific, mission-critical application.**
- **Is not adequate for other provenance use cases, such as monitoring data exfiltration:**



Challenges

Will our approach conflict with other reduction techniques?

What to collect? | *What to keep?* | *How to store?*

Tasks:

Specify scope of provenance collection	Reduce dependence explosion, collapse cycles, compact into supernodes, remove attributes.	Provenance-agnostic compression, optimize for storage and/or query.

Related Works:

- **Provenance Walls** [Bates et al. 2015]

- **BEEP** [Lee et al. 2013]
- **Provenance Sketches** [Malik et al. 2010]
- **PASS** [Muniswamy-Reddy et al. 2006]

- **Web / Deduplication** [Xie et al. 2011]
- **Web + Dictionary** [Xie et al. 2012, 2013]

Conclusion

- We are investigating MAC enforcement as a means of reigning in the scope of provenance collection.
- Depending upon the application, the savings are potentially large (82% storage reduction).
- Secure computing deployments not only provide an interesting use case, but also create new opportunities to address open challenges in provenance collection.
- LPM makes it easier to prototype provenance monitors, and simultaneously assures that collection mechanisms are tamper proof and have complete mediation of system activity.

Questions?

Thank you for your time.

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Linux Provenance Modules will be available in August at

http://linuxprovenance.org