Privacy-Enhancing Models and Mechanisms for Securing Provenance and its Use

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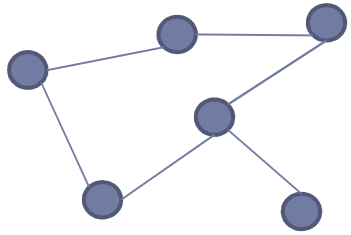
Provenance Helps Enhance Security

Access and Usage Control
of Data and its Provenance

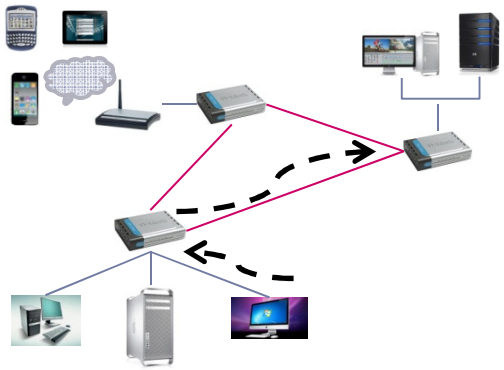
Data Trustworthiness
(e.g., sensor networks)



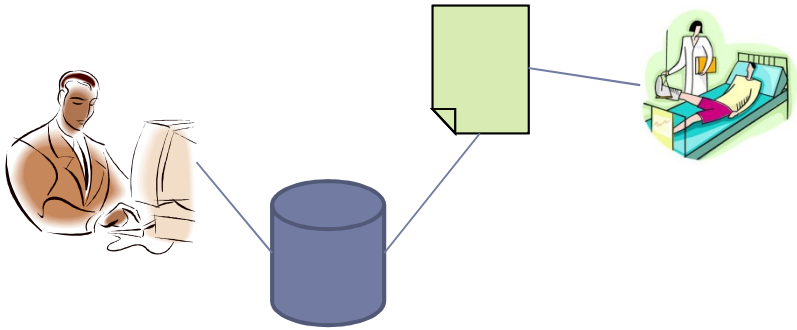
Data

Provenance

Data Forensics
(e.g., SIM tools)



Data Privacy
(e.g., track hospital records)

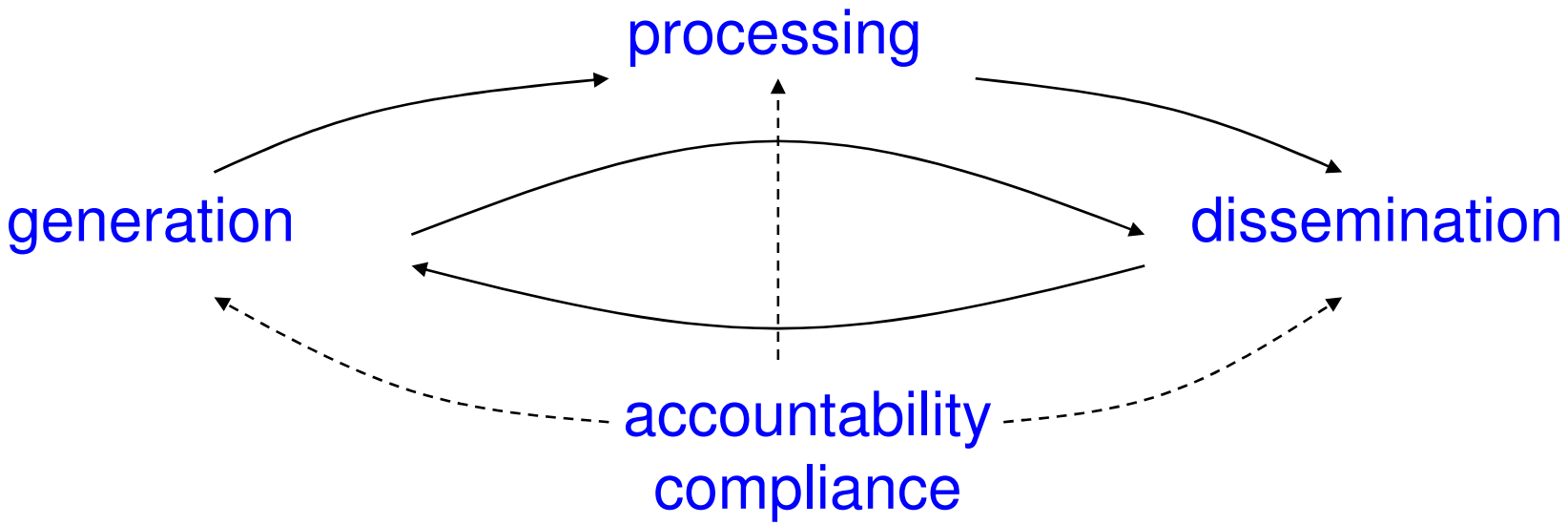


etcetera

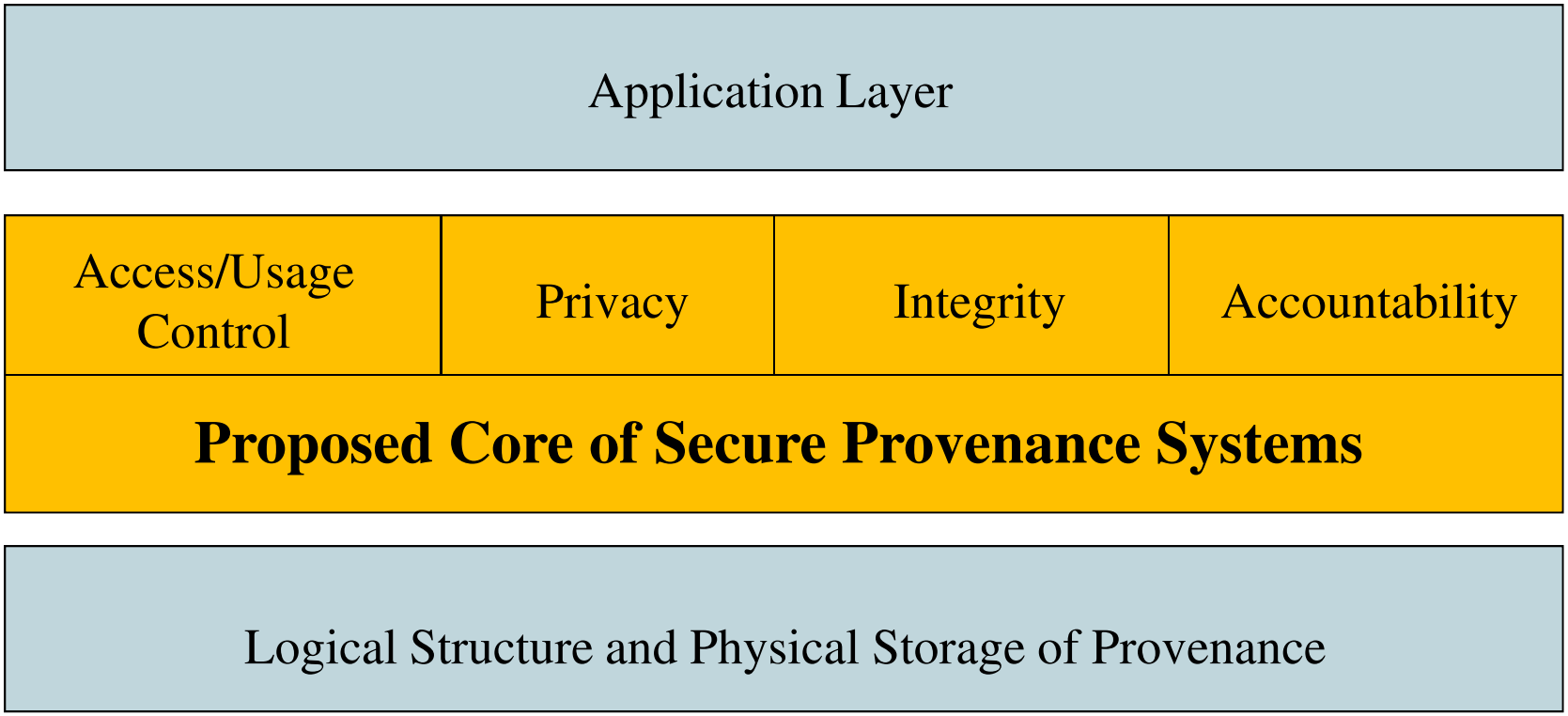
But Provenance Itself Must Be Secured!

- Security Requirements for Provenance
  - Access and Usage Control
    - Only authorized users may access provenance, and data based on provenance for appropriate purpose
  - Privacy
    - Provenance disclosed at a level that preserves data and source privacy
  - Integrity
    - Ensure that provenance is authentic and not tampered with
  - Accountability
    - Subjects accountable for data changes, even when they are anonymous
- Contributions
  1. Privacy-enhancing framework (i.e., models and mechanisms) for securing provenance lifecycle
  2. Design and implementation of mechanisms for secure provenance management at OS layer and Data Layer

Provenance Life Cycle



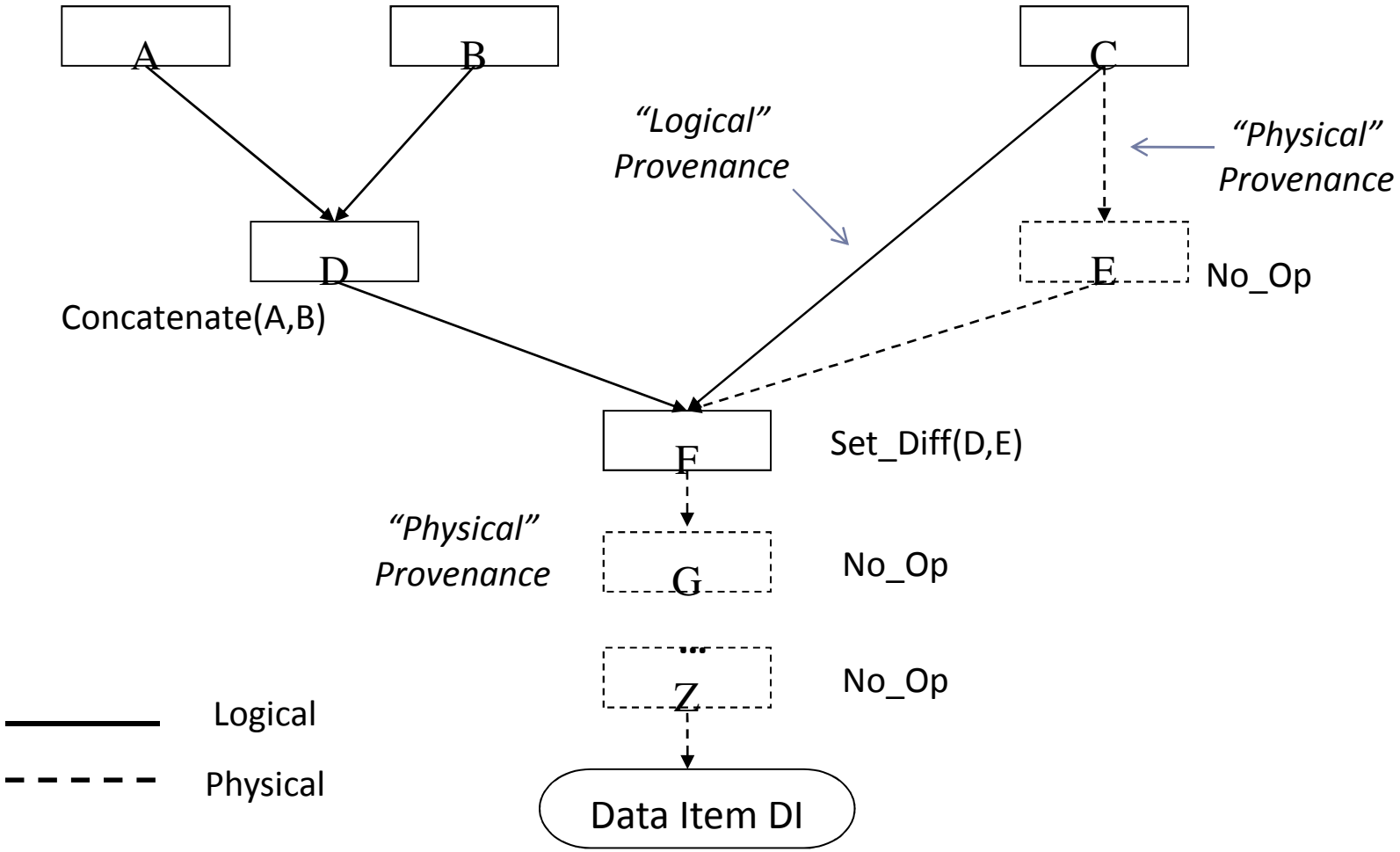
Proposed Secure Provenance Core Layer



Representation of Provenance

- Directed Acyclic Graph (DAG)
  - Nodes represent entities (sources) that forward/modify data
  - Node labels capture type of operation performed
    - E.g., concatenation, set difference, etc.
- Edges capture data flow
  - Logical and physical provenance
    - Logical provenance captures actual changes in data
    - Physical provenance models "forwarding only" cases
  - People and system/machine provenance
    - People attributes changes in data to a person or organization
    - System/machine tracks provenance wrt software/hardware

Provenance DAG Example

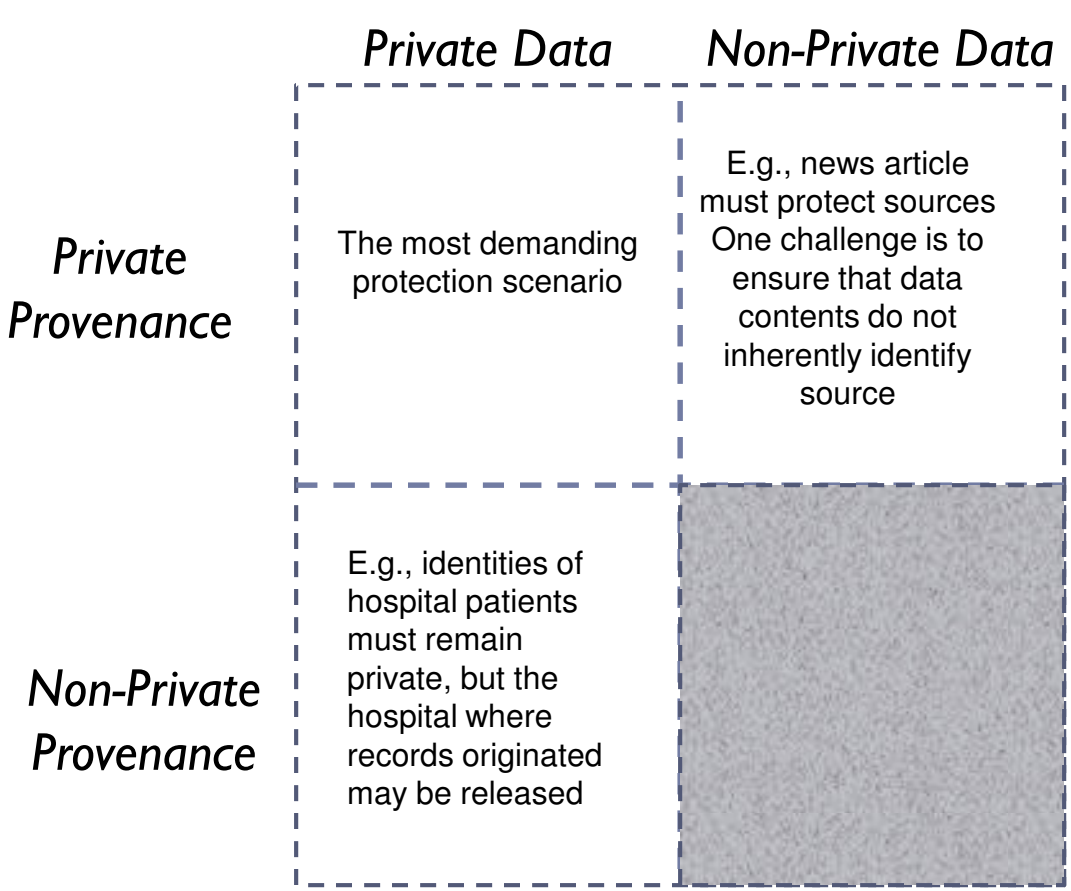


Access/Usage Control: Challenges

- Traditional access control models not applicable
  - Existing techniques do not apply to DAGs*
- Complexity of authorization conditions
  - Authorization may depend on sequence of operations performed by sources
  - Changes in policy
- Conflict resolution
  - Sources that contribute to the same data object may have conflicting policy requirements
  - Reconciliation of source and recipient policies

* U. Braun et al, "Securing Provenance", In Proc. of HotSec '08

Privacy Challenges and Techniques



- Sanitization
  - Release provenance at appropriate granularity levels
  - Generalize provenance
    - E.g., instead of releasing employee and department name who modified document, only release organization name
- Cryptography
  - Employ advanced cryptographic techniques that allow private evaluation of conditions
    - E.g., private similarity evaluation of two provenance DAGs

Integrity & Accountability: Challenges and Techniques

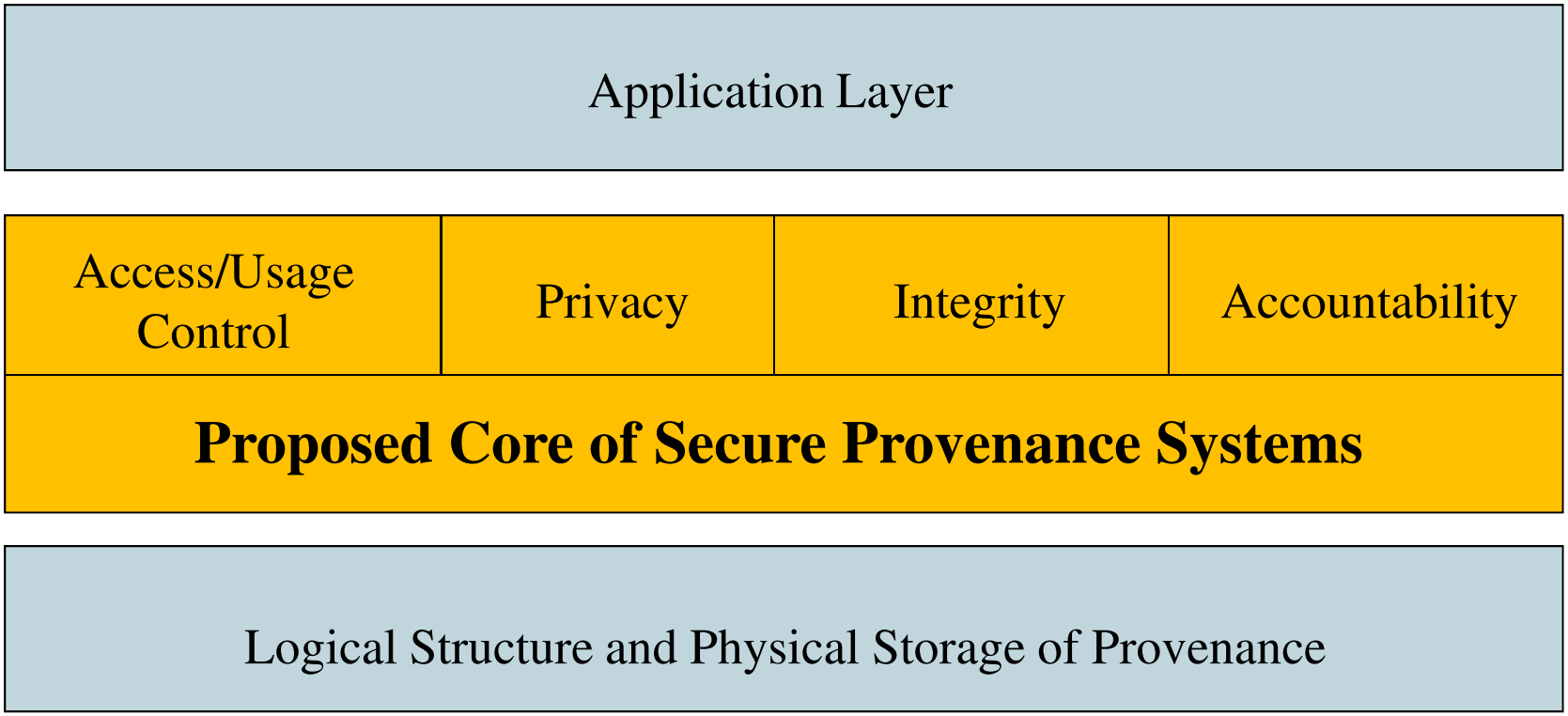
- Integrity:
  - Authenticate source and content of provenance information
- Accountability
  - Non-repudiation of a source's role in the provenance chain even if annonymized for privacy
- Techniques
  - Conventional digital signatures may not be suitable
    - Provenance is highly dynamic and may include multiple sources that may not know/trust each other
    - Sources may need to remain anonymous
  - Non-interactive Editable Signatures for Provenance
    - Novel cryptographic techniques

Prototypes

1. Secure Provenance Management for OS
   - Provenance protection is achieved through trusted VMMs running within a higher trust domain than the OS
   - OS-independent mechanism, where provenance is embedded as watermark in the data
     - Maintains compatibility with existing applications

2. XML Document Dissemination System
   - Provenance is maintained at XML element level (fine-grained)
   - Protection through cryptographic tokens

Summary



- Contributions

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