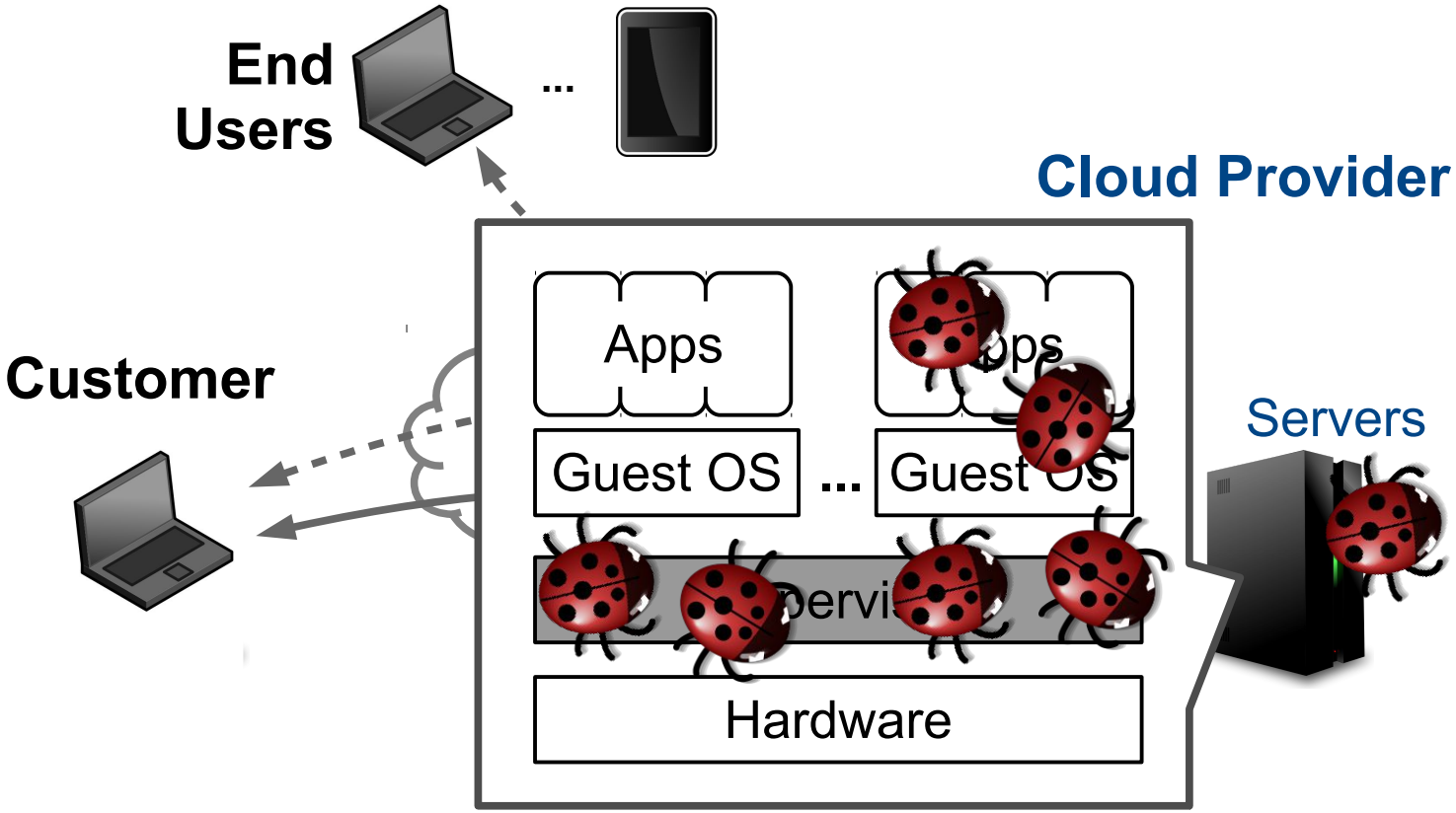
Towards Trustworthy Architectures for Secure Cloud Servers and End-User Devices

Jakub Szefer and Prof. Ruby B. Lee
Princeton University

http://palms.princeton.edu/

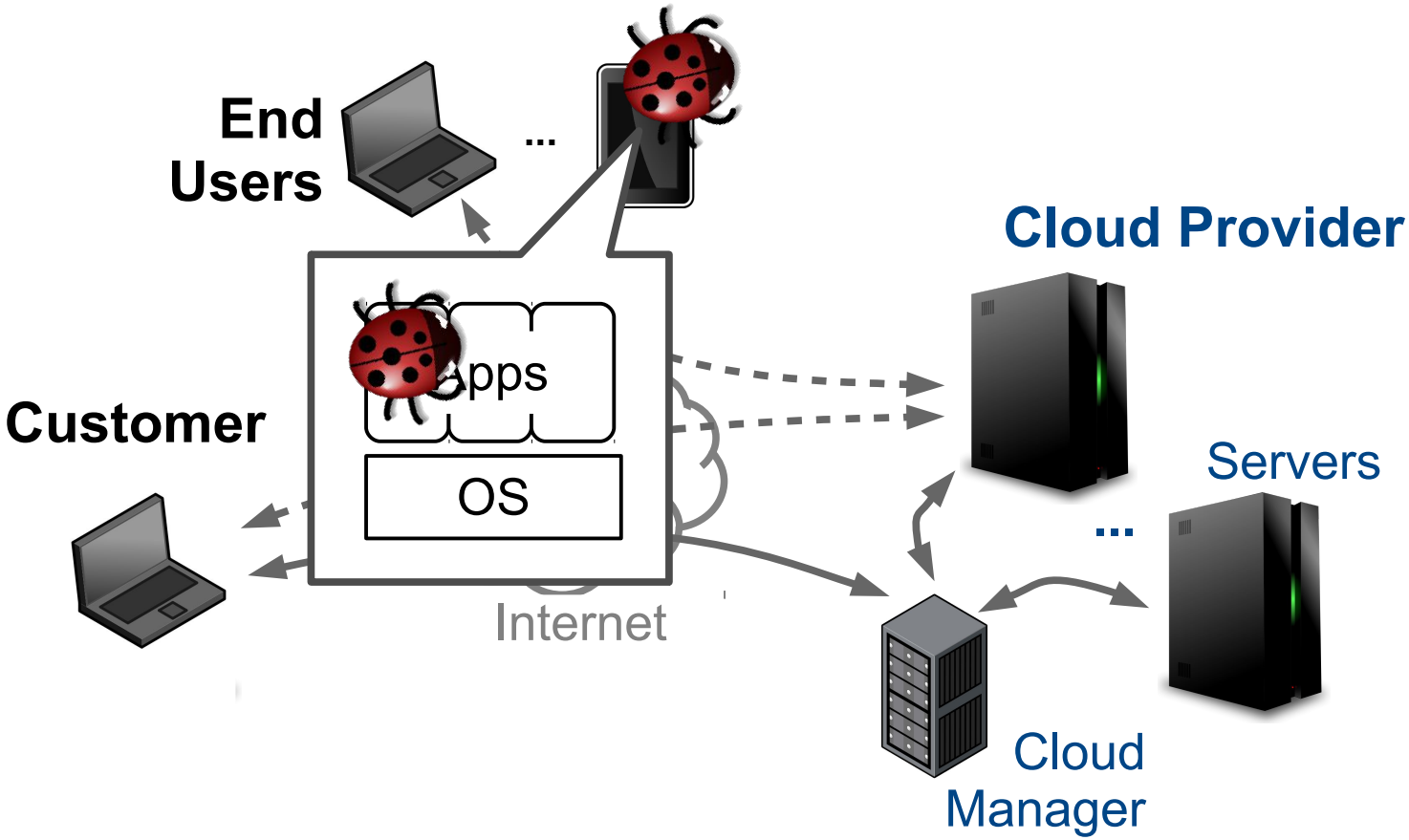
Security Challenges to Cloud Servers

- Security challenges arise from sharing resources with unknown people, no control over management software, and unknown insiders where servers are located



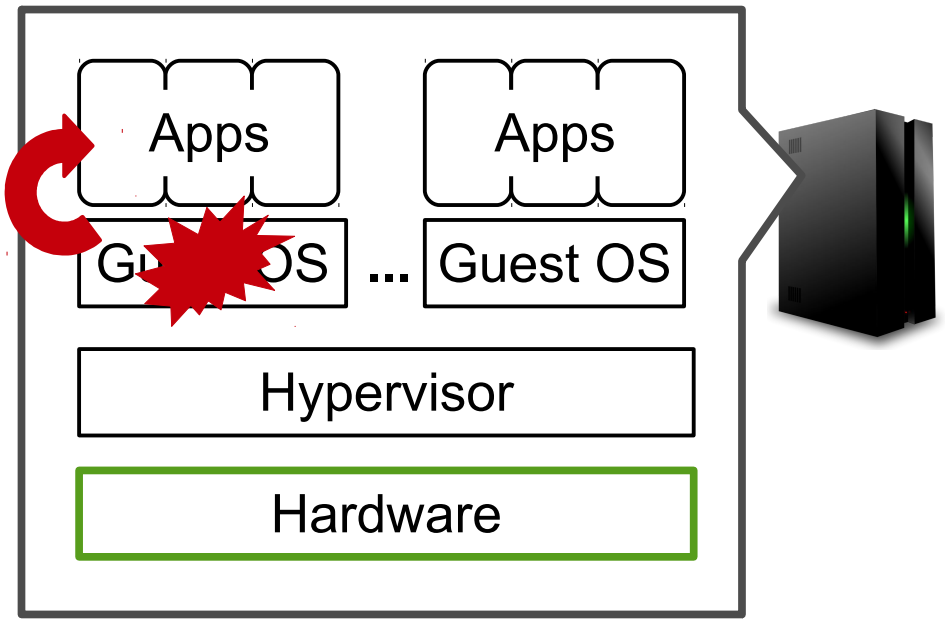
Security Challenges to End-User Devices

- Challenges arise due to unvetted third-party applications or loss of the physical device



Leveraging Hardware for Security

- Hardware prevents attacks “from below”, it's lowest level in the system
- Hardware security:
  - performance
  - immutability
  - secret recovery prevention
- Can leverage existing hardware or propose new to meet the threat model



Hardware System Lifecycle

- Hardware can provide protections at all points in the lifecycle of cloud servers or end-user devices

- **Hardware can measure and protect**:
  - measure code, data, and metadata
  - protect code, data, and metadata
  - store secrets (keys)

- **Hardware should be attested**:
  - ensure proper hardware is installed
  - validate configuration
  - check protections are being enforced

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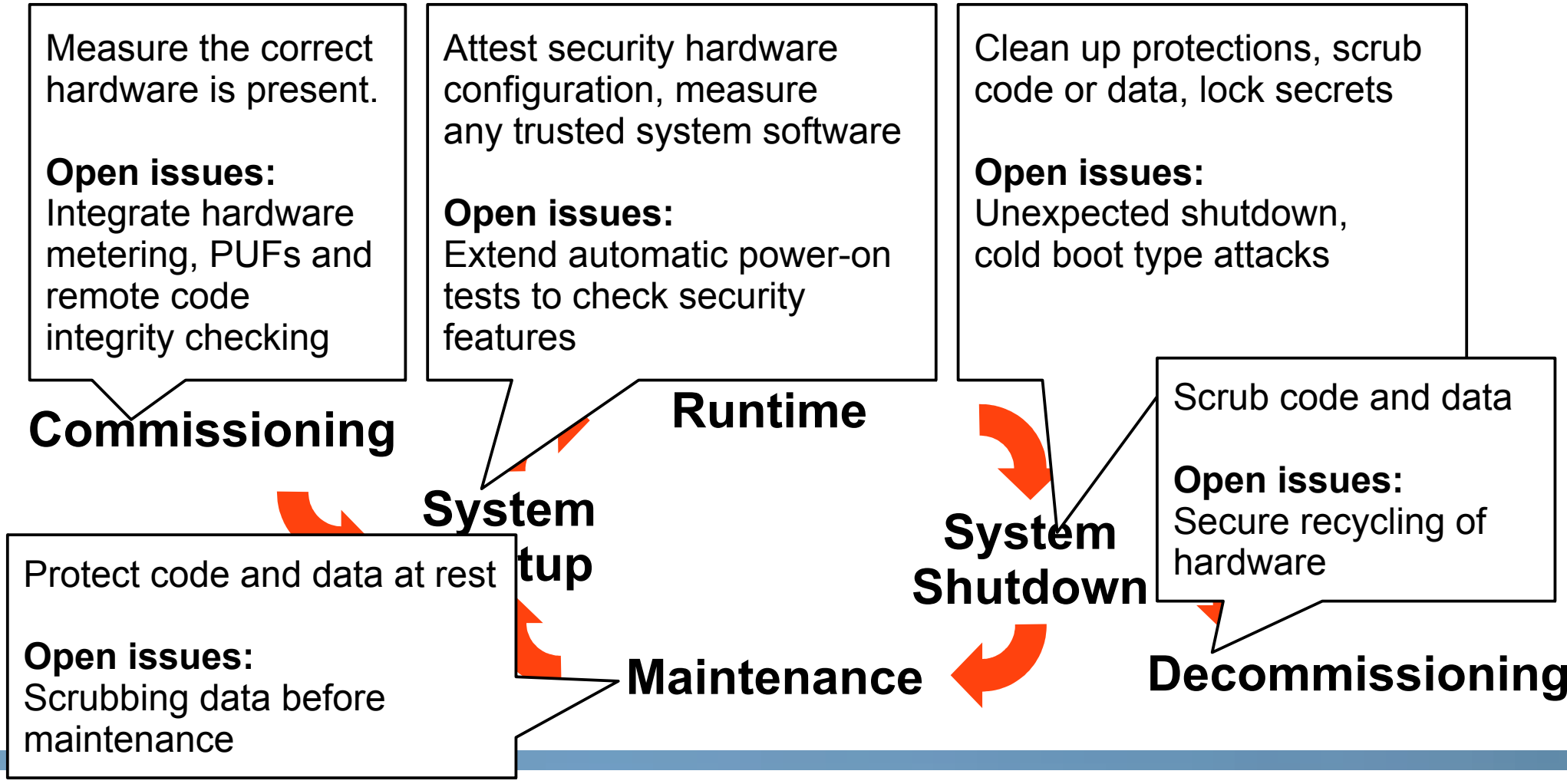
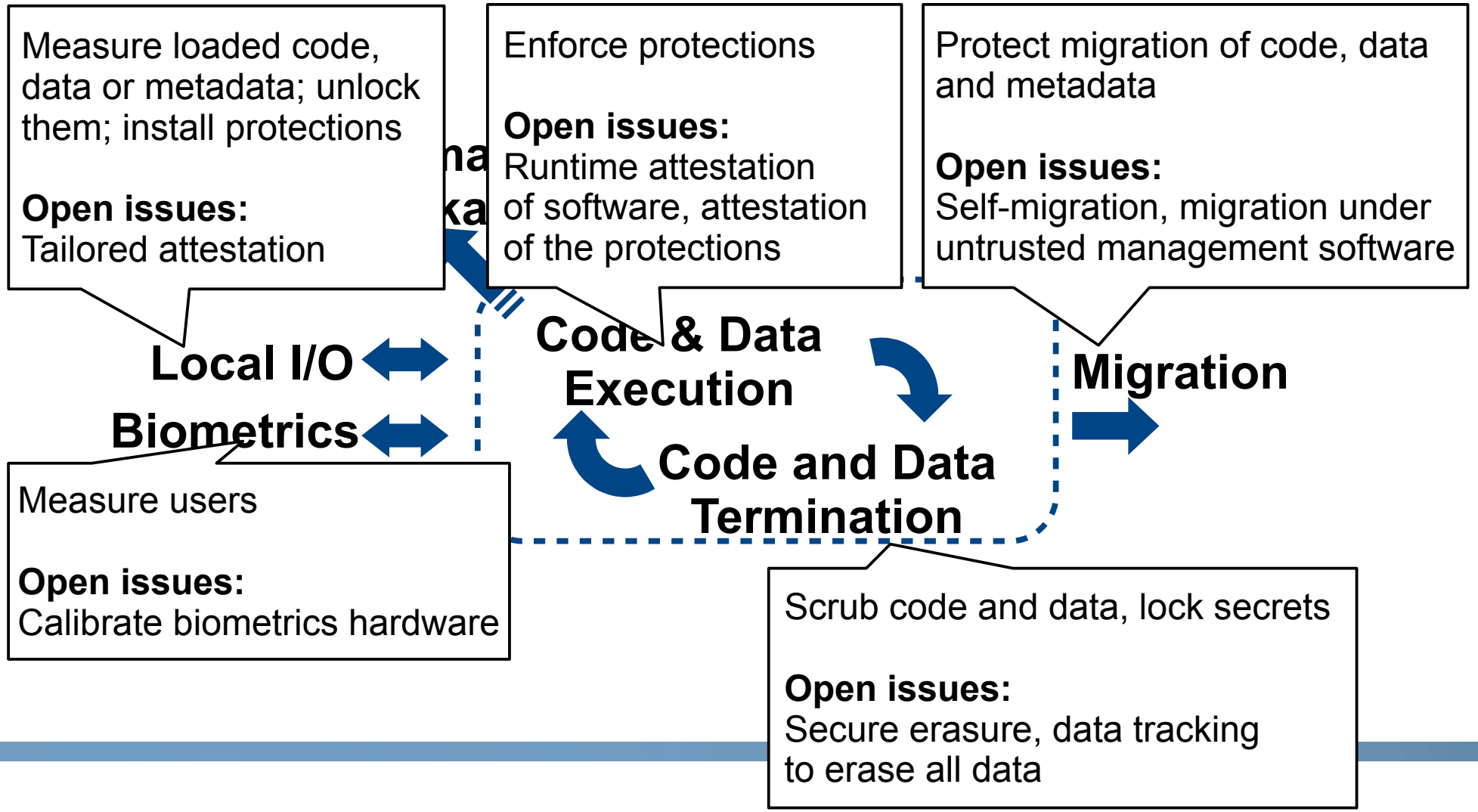


Hardware System Lifecycle

- Runtime protections and measurements; need to protect code, data and metadata



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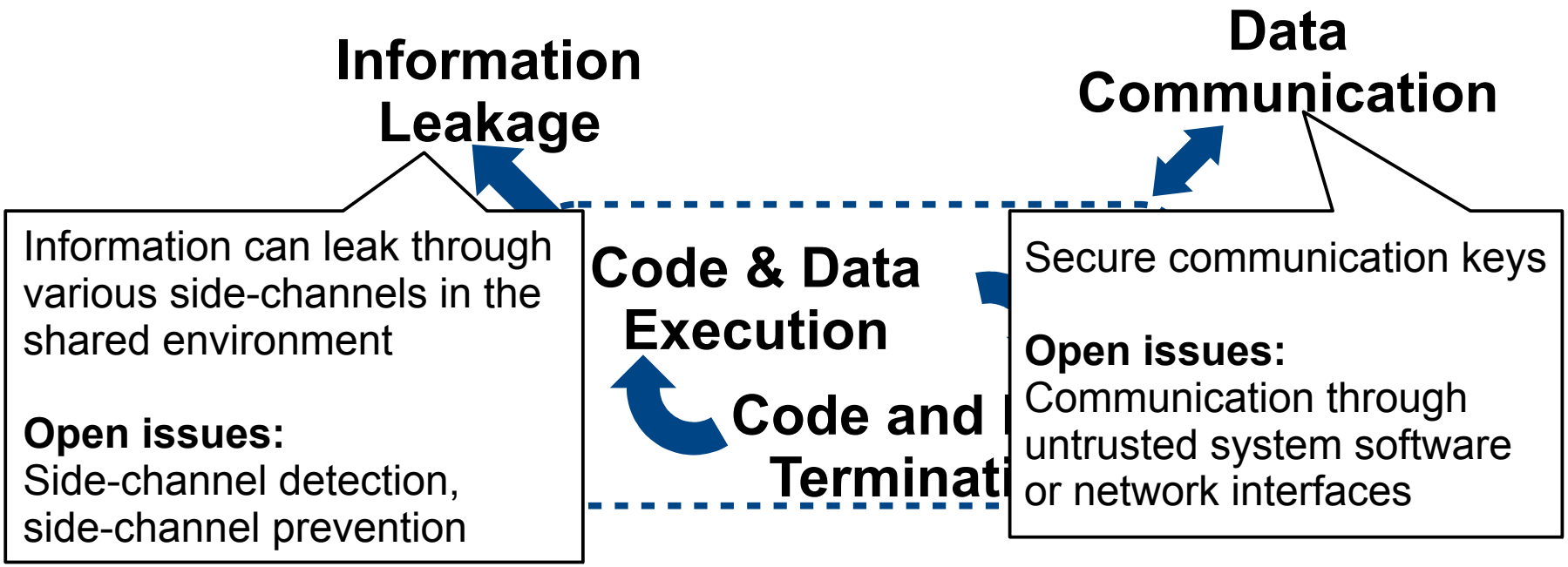


Research Questions

- How to verify that the design is correct?
- How to attest that the protections mechanisms are working?
- How to attest enforcement of the correct protections?
- How to leverage existing hardware or environment?
  - Insider threats and physical attacks
- How to protect lost or stolen devices?

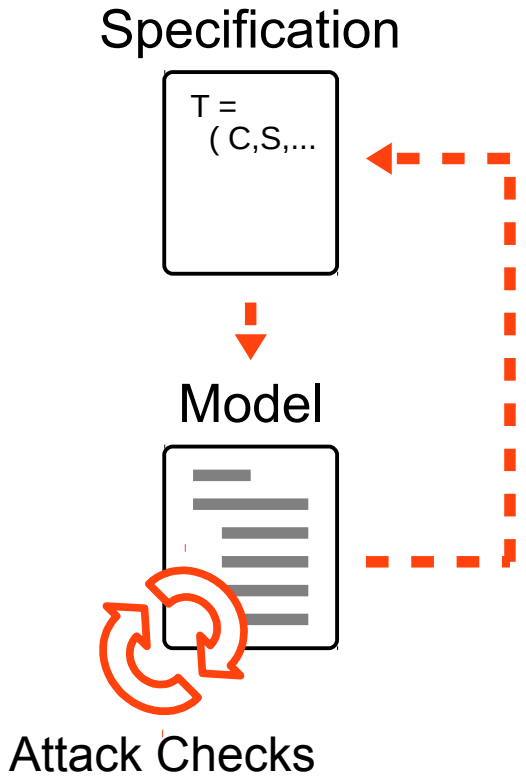
Verifying Security of the Design

- Before committing to hardware, need to raise confidence in the design
- Many tools available for security protocol testing: HERMES, Casrul, AVISPA, Scyther, ProVerif, Athena, …
- Want similar tool(s) for secure architectures
- Work exists on formal verification of whole architectures, but needs large teams, long time; verifying individual parts can also give good results*

* Composition is very important unsolved problem.

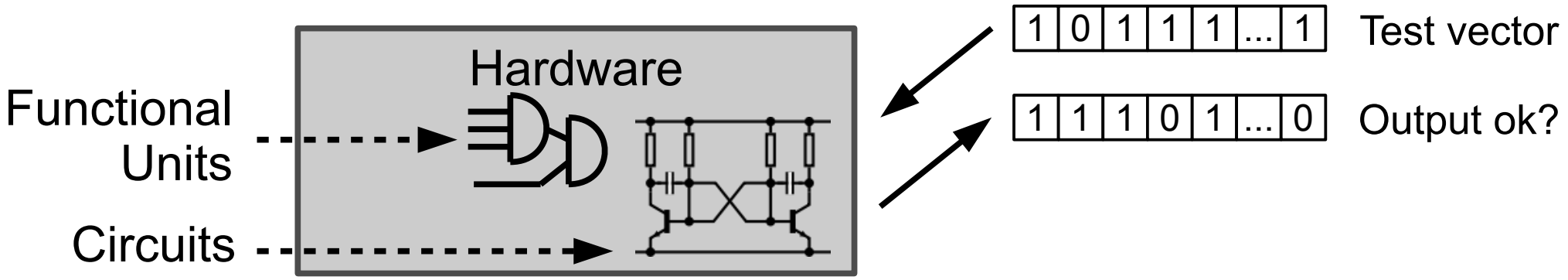
Verifying Security of the Design

- Proposition: verify critical interactions and mechanisms
- Goal to leverage existing tools that architects know how to use
- Augment functional verification with checks for security problems
- Design heuristics to generate security invariants that check for attacks based on attacker capabilities



Attesting Protection Mechanisms

- Hardware security mechanisms need to be checked that indeed they offer the advertised protections
- Power-on testing is used for error checking, expand for security checks
- **Challenge-response** tests



Attesting Protection Mechanisms

- Hardware security mechanisms need to be checked that indeed they offer the advertised protections
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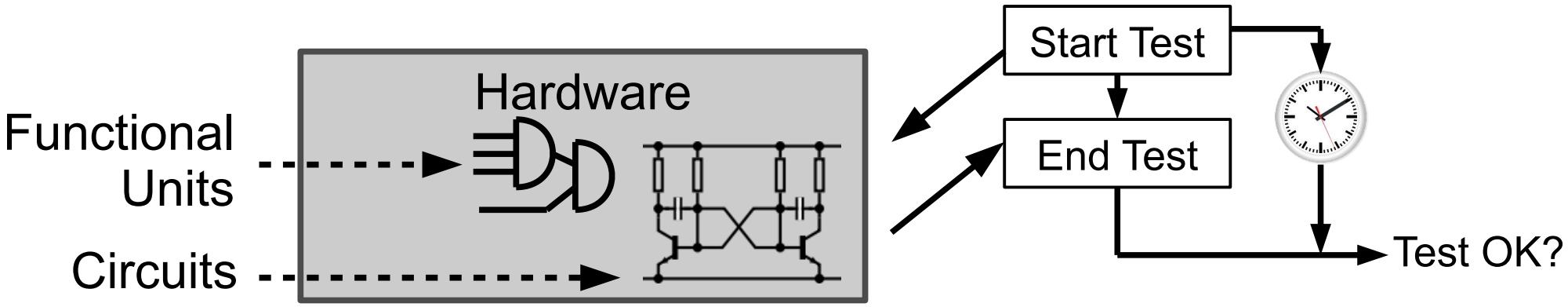
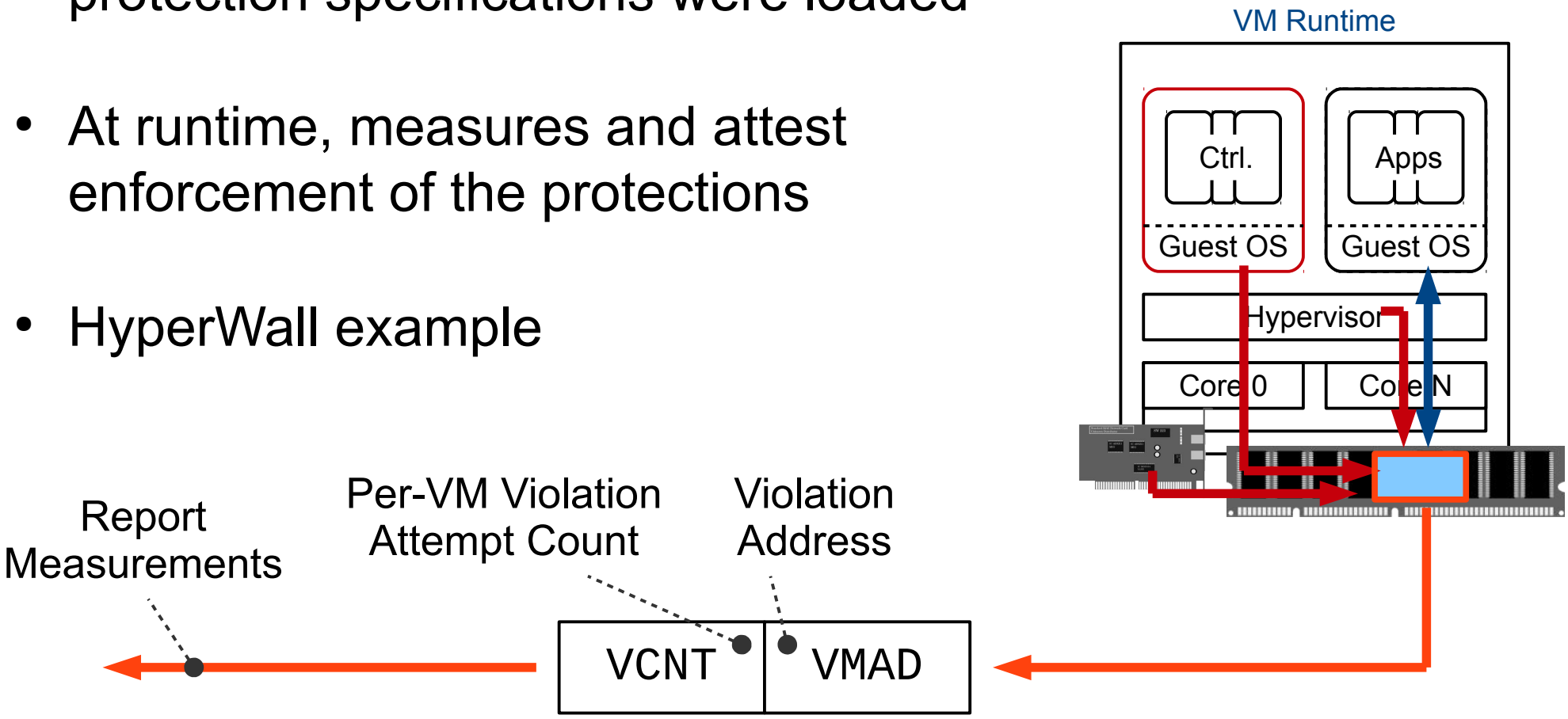
- **Time-based** tests



Attesting Enforcement of the Protections

- At startup, measure and attest correct code, data, and protection specifications were loaded
- At runtime, measures and attest enforcement of the protections
- HyperWall example



Leveraging Existing Hardware

- Existing hardware can also be used if it can be applied correctly

- Hardware manufacturers offer many **performance** enhancing features in commodity microprocessors, e.g.
  - Ring-based hierarchical protection
  - Memory translation hardware
  - Data structures for controlling world switches
  - Hardware virtualized devices

- **Leverage the hardware for security**

Leveraging Existing Hardware

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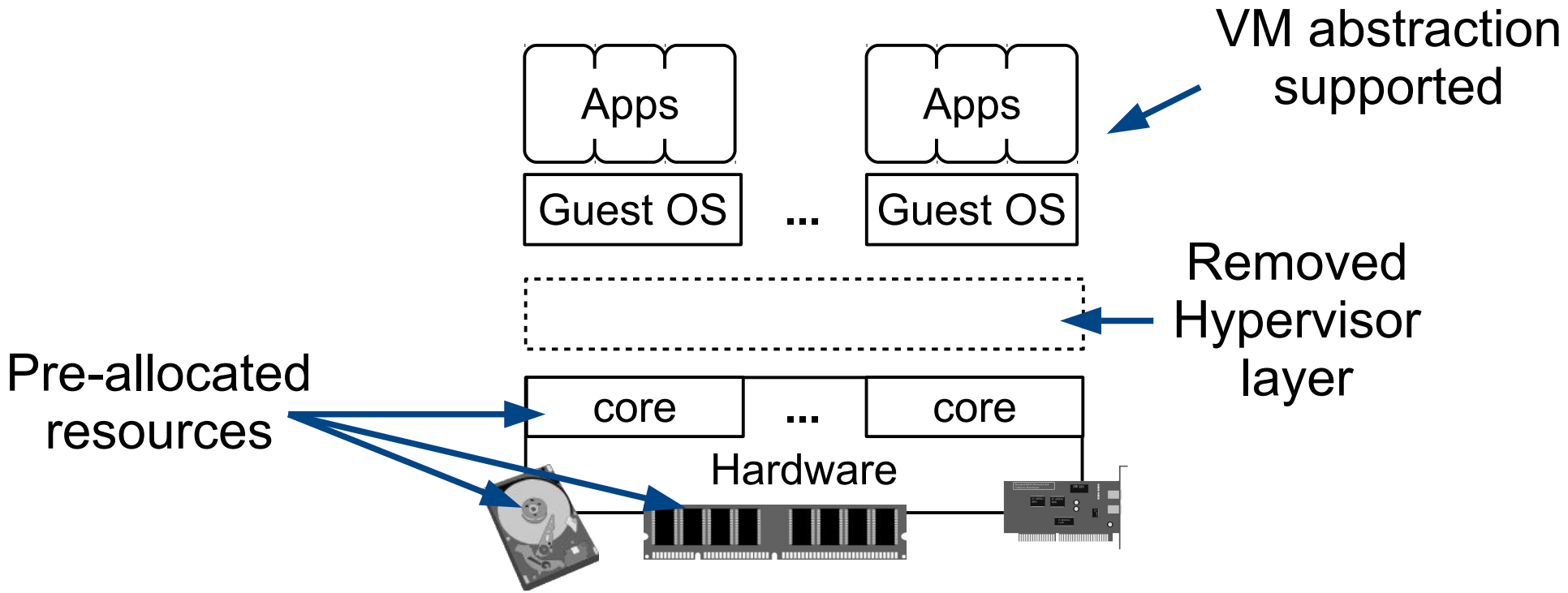
- NoHype example

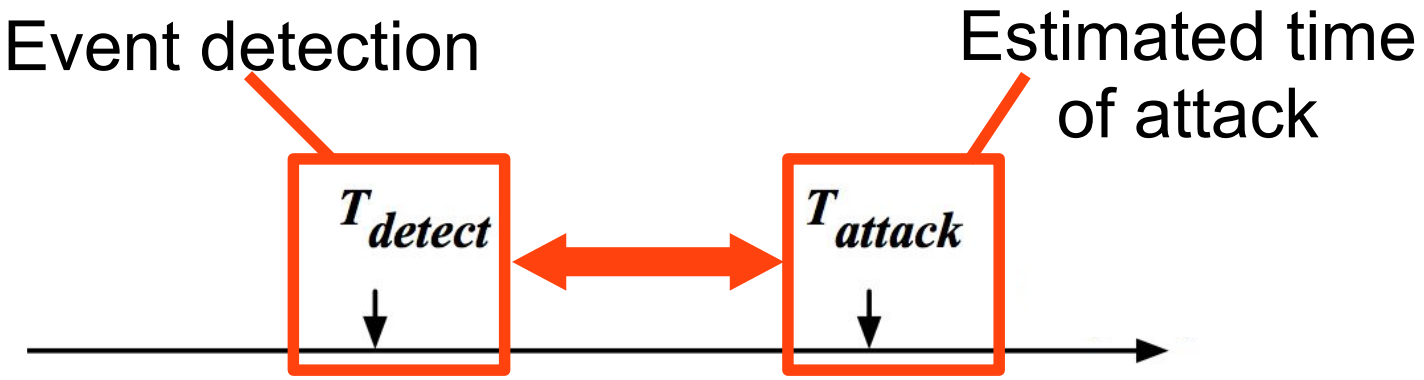


Leveraging Existing Environment

- Environment of the cloud server or end-user device is usually assumed neutral or adversarial
- **Can we use the environment to our benefit?**
- E.g. end-user devices are often mobile, connect from different locations, etc.
- E.g. cloud servers, are often used in data centers, many redundant network connections, many other servers near by, many sensors, etc.

Preventing Insider Threats

- Data centers are becoming backbone of computing, they have their unique threats, e.g. insider threats
- But also unique opportunities as in the available sensors that measure environment around the server
- Can leverage sensors for physical insider threat prevention



Lost or Stolen End-User Devices

- Devices are portable, can be lost or stolen while users are logged in
- One-time user authentication is not sufficient, can we leverage behavior to **continuously authenticate users through hardware sensors**?
- Software behavior will be different when new person picks up the device; can we leverage **performance counters and hardware events to detect malicious behavior**?

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Thank you!

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