Advanced Systems Security: Trusted Computing

Presented by Joshua Schiffman

Trent Jaeger
Systems and Internet Infrastructure Security (SIIS) Lab
Computer Science and Engineering Department
Pennsylvania State University

April 20, 2010

Problem

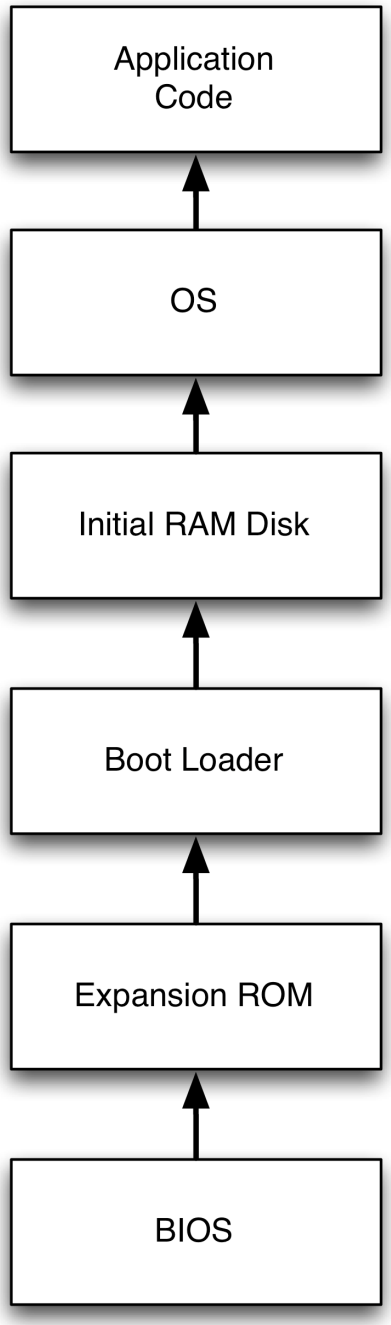
- My computer is running a process
- It makes a request to your computer
  - Asks for some secret data to process
  - Provides an input you depend on
- How do you know it is executing correctly?
- Example
  - ATM machine is uploading a transaction to the bank
  - How does the bank know that this ATM is running correctly, so the transaction can be considered legal?

What would you do?

- Nothing
- Proof by authority (Certificates)
  - Tells you who, but not what
- Constrain the system (Secure Boot)
  - Effective, limiting, but proof is implied
- Inspect the runtime state (Authenticated Boot)
  - Flexible, attestable, but difficult to prove semantics

Secure Boot

- Check each stage in the boot process
  - Is code that you are going to load acceptable?
  - If not, terminate the boot process
- Must establish *a* ***Root-of-Trust***
  - A component trusted to speak for the correctness of others
  - Assumed to be correct because errors are **undetectable**



AEGIS

- AEGIS architecture (1997)
  - ROM checks the BIOS
  - BIOS checks expansion ROMS and boot block
  - Boot Loader checks the OS
- Why not just boot from a floppy (DVD now)?
- Is this a root of trust?
- What can it verify?
- How do we know it booted securely?

Authenticated Boot

- Secure boot enforces requirements and uses special hardware to ensure a specific system is booted
  - Implied verification (Good because it is)
- By contrast, we can **measure** each stage and have a verifier authenticate the correctness of the stage
  - Verifier must know how to verify correctness
  - Behavior is uncertain until verification
  - Can you verify yourself?
- What is our root-of-trust?

Outbound Authentication

- Applied to the IBM 4758 by Smith (ESORICS 2002, Int J Inf Security 2004)
- *Goals*: Securely boot the 4758 and prove to remote parties (combines secure boot and attestation)
- More specifically, relying party *P* wants to prove that only entity *E* holds key *K*
  - *E* is high integrity despite depending on several integrity-relevant events (e.g., boot and upgrade)
- *Defines a precise logic for reasoning about such properties*
  - But, the 4758 is a very limited system (one application)

IBM 4758

- *"A relying party needs to conclude that a particular key pair really belongs to a particular software entity within a particular untampered coprocessor."*
- Why does this prove the integrity of the processing environment?
- What else is needed to make this connection between the key and entity's correctness?
- IBM 4758 Secure coprocessor contains various hardware protections to isolated memory, manage keys, and perform updates.

Configurations and Epochs

- A *Layer N configuration* is the maximal period in which that layer is run-able, with an unchanging software environment in Layers 1, …, N
- A *Layer N epoch* is the maximal period in which the layer can run and accumulate state.
- Software runs for an epoch, but any change to the software (integrity-relevant event) results in a new configuration
  - Hardware constrains these events
- What are other integrity-relevant events in conventional systems?

Execution History

- *E* wishes to prove it "owns" *K* by presenting a *Chain(E, K, H)* of certificates
  - H shows the chain of entities that certify E's K before the current run R.
  - The chain speaks for the correctness of K, which the relying party P should trust.
- Implications: Only these entities should have access to the secrets and configuration of E
  - Hardware limits the set of integrity-relevant operations that can affect E
  - General purpose systems allow more operations

Dependency (Integrity)

- Each entity *E* has a dependency set *D(E)*
  - An entity E depends on entities that have read/write access to its secrets and write access to its code
    - In general purpose systems, it is primarily dependence on untrusted data that leads to integrity problems
- *TrustSet(P)* – set of entities that P trusted
  - *TrustSet(P)* should be a superset of the measured dependencies
- Implications
  - Dependency must be comprehensively defined
    - Initialization, Code Load, Subsequent Reads

Validation

- P wants to verify E depends only on its TrustSet(P)
  - A run R, prefixed by H, defines an entity's $D_R(E)$

$$Validate(P, Chain(E, K, H)) \Rightarrow D_R(E) \subseteq TrustSet(P)$$

  - Hardware protections imply $D_R(E)$
  - If $D_R(E)$ is in P's trust set, then the chain is valid

$$D_R(E) \subseteq TrustSet(P) \Rightarrow Validate(P, Chain(E, K, H))$$

- OA requires an entity E's dependencies satisfy the trust set of P to validate that E owns K

Validation Implications

- Difficult for P to verify all entities, integrity relevant events, and dependencies
  - We just want a green light (iTurtle)
- Enforcement simplifies the protocol
  - OA makes this seem easy, but has a lot of constraints to simplify the problem

Trusted(?) Computing

- The Trusted Platform Module (TPM) brought authenticated boot into the main stream
- Essentially, the TPM offers few primitives
  - Measurement, cryptography, key generation, PRNG
  - Controlled by physical presence of the machine
  - BIOS is Core Root of Trust for Measurement (CRTM)
- Spec only discussed how to measure early boot phases and general userspace measurements

Authenticated Boot

- A lot of FUD and hate was generated around what it does and does not do
- Paladium/NGSCB architecture (Microsoft, 2002)
  - Use virtualization to split system
  - Measure the "trusted" part to prove its integrity before responding
- *"Meet the emerging requirements of an interconnected world" -- Microsoft*
- *Take over the world – Ross Anderson and others*

Linux Integrity Measurement

PENNSTATE 1855

- Problem: How can we verify the software environment of networked systems?
- Solution: Extend TPM measurement architecture to measure system's runtime (Software Stack)
- Additional Goals
  - Load-time integrity
  - Unobtrusive
  - *Tamper-evident*
  - Usability

IMA

- System integrity depends on several components
  - Executables
    - Programs, libraries, kernel modules
  - Configuration Files
    - httpd.conf, /etc/shadow
  - Unstructured Input
    - Network data, keystrokes, basically everything else

IMA Implementation

- Place hooks throughout Linux kernel
  - Later added as an LSM and then special LIM hooks
- Extend TPM PCR at file load-time
  - PCR = SHA1(File || PCR)
- Applications instrumented to measure inputs
  - Bash scripts, interpreters…
- Verifying all events is difficult
  - Need known "good" values to validate measurements
  - Leverage OS distribution definitions

Limitations

- What does IMA prove?
- Can a system with a valid IMA attestation be malicious?
- What else can be done to improve attestations?

Take Away

- Programs on systems may be security-critical
  - How do we determine if they are up to the task?
- Secure and authenticated boot processes enable a party to prove a system's integrity satisfies some requirements
  - Secure boot proves to local parties
  - Authenticated boot for remote parties
- OA provides secure boot and authenticate boot for comprehensive control – of a simple device
- IMA provides authenticated boot for Linux