ArmoredSoftware

User-Space Remote Attestation

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Clouds and Trust

- The promises of “the cloud” are substantial
  - reduced hardware and software costs
  - reduced resource consumption
  - improved availability and reliability
- The promises of “the cloud” complicate assurance
  - not under the desk
  - ambiguous and changing runtime environment
  - unknown and unknowable actors in the same environment
- Is trust possible in “the cloud” environment?
  - unambiguous identification
  - confirmation of uninhibited execution
  - direct or trusted indirect observation of good behavior

Trust in the Cloud

Provide new capabilities that establish and maintain trustworthy cloud-based application deployment

- Establish trust among cloud components
  - trust among cohorts of processes
  - trust among processes and environment
- Promote informed decision making
  - data confidentiality can be confirmed
  - execution and data integrity can be confirmed
- Autonomous run-time response and reconfiguration
  - responds to attack, failure, reconfiguration, and repair
  - response varies based on measurement

Delivery Platform

Open source, standards compliant

- Lightweight integration with existing cloud infrastructure
  - OpenStack cloud infrastructure
  - Xen+XSM VM infrastructure
  - Fedora, HotSpot JVM, GHC
- Trusted Computing Group standards compliant
  - Trusted Platform Module 1.2
  - TCG vTPM (in principle)
  - Trusted OS infrastructure
- Standard communication mechanisms
  - JSON structures for all exchanged data
  - *vchan* for on-platform communication
  - TCP/IP for off-platform communication

New Technologies

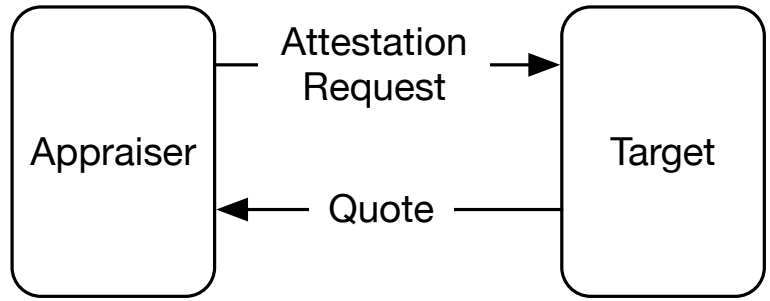
- Trustworthy protocol execution
  - executable protocol representation
  - protocol execution generates evidence of trustworthiness
  - highly focused protocols
  - strand space formal semantics
- Application specific measurement
  - managed and traditional execution environments
  - compile-time assistance for measurer synthesis
  - specialized measurement bundled with applications
- Attestation driven cloud application and data management
  - health monitoring
  - problem mitigation
  - application migration
  - access control

Trusted Platform Module

- Provides and Protects Roots of Trust
  - Storage Root Key (SRK) - root of trust for storage
  - Endorsement Key (EK) - root of trust for reporting
- Quote generation
  - high integrity quotes - ($\{|RS|\}_{AIK^-}$, SML, $\{|n, PCRComp|\}_{AIK^-}$)
  - high integrity evidence - ($\langle E, n \rangle$, $\{|\,|\langle E, n \rangle|, PCR|\}_{AIK^-}$
- Sealing data to state
  - $\{D, PCR\}_{K^+}$ will not decrypt unless PCR = current PCR
  - data is safe even in the presence of malicious machine
- Binding data to TPMs and machines
  - ($\{K^-\}_{SRK^+}$,K) - $\{D\}_{K^+}$ cannot be decrypted unless SRK^- is installed
  - ($\{J^-\}_{K^+}$,J) - $\{D\}_{J^+}$ cannot be decrypted unless K^- and SRK^- are installed

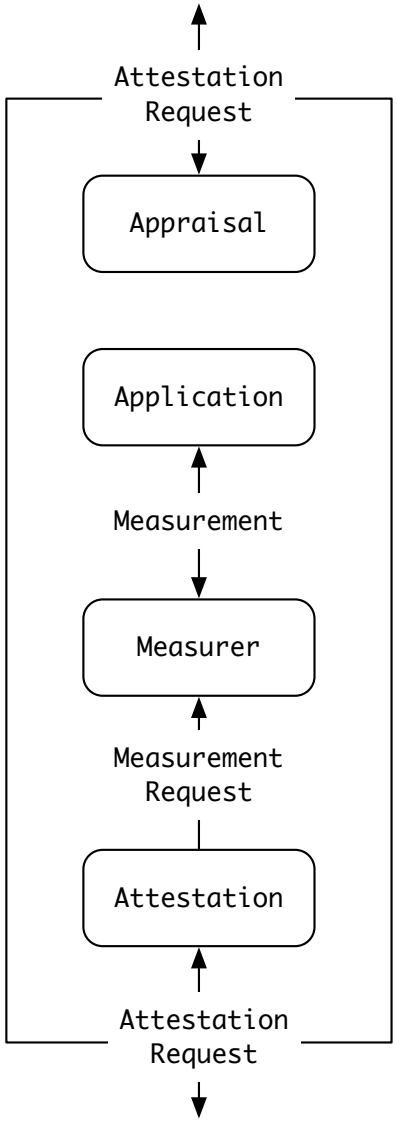
Semantic Remote Attestation

- Appraiser requests a quote
  - specifies needed information
  - provides a nonce
- Target gathers evidence
  - measures application
  - gathers evidence of trust
- Target generates quote
  - measurements and evidence
  - original nonce
  - cryptographic signature
- Appraiser assesses quote
  - good application behavior
  - infrastructure trustworthiness

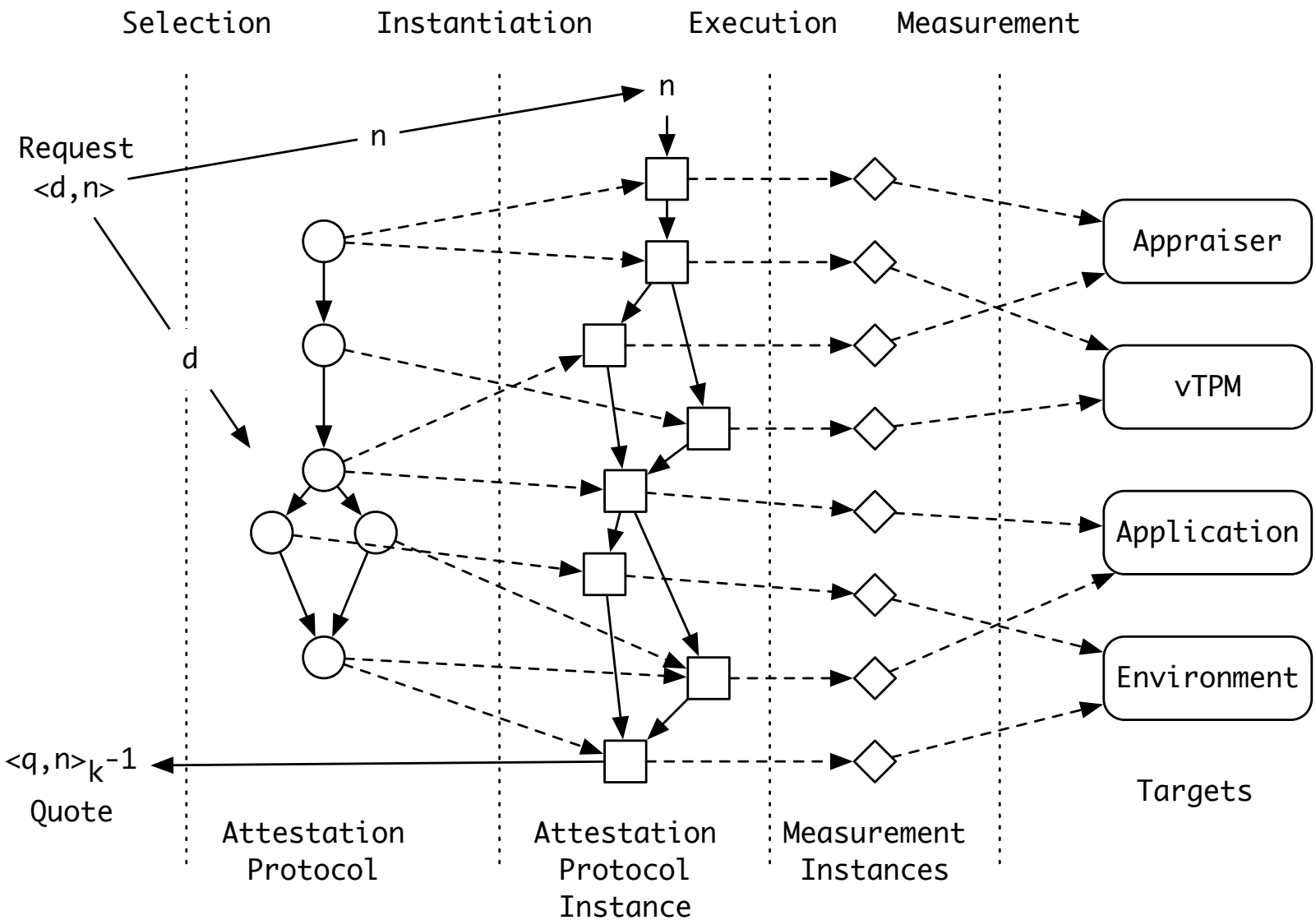


Armored Application Architecture

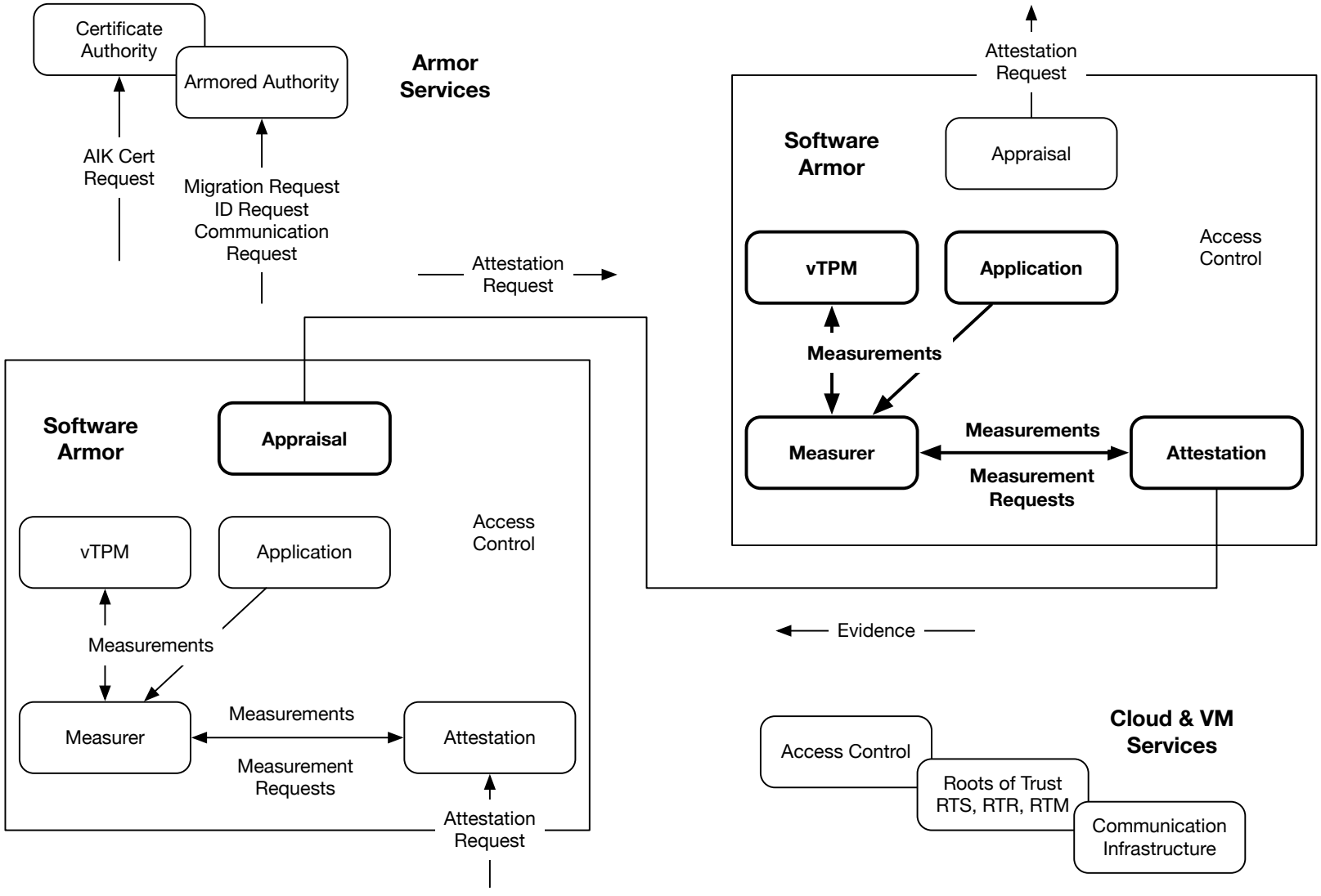
- Focus is user-space applications
- Assesses the cloud infrastructure and environment
- Attests to the state of its application
- High-assurance, lightweight infrastructure
- Influenced by the *Trusted Research Platform* and *Principles of Remote Attestation*



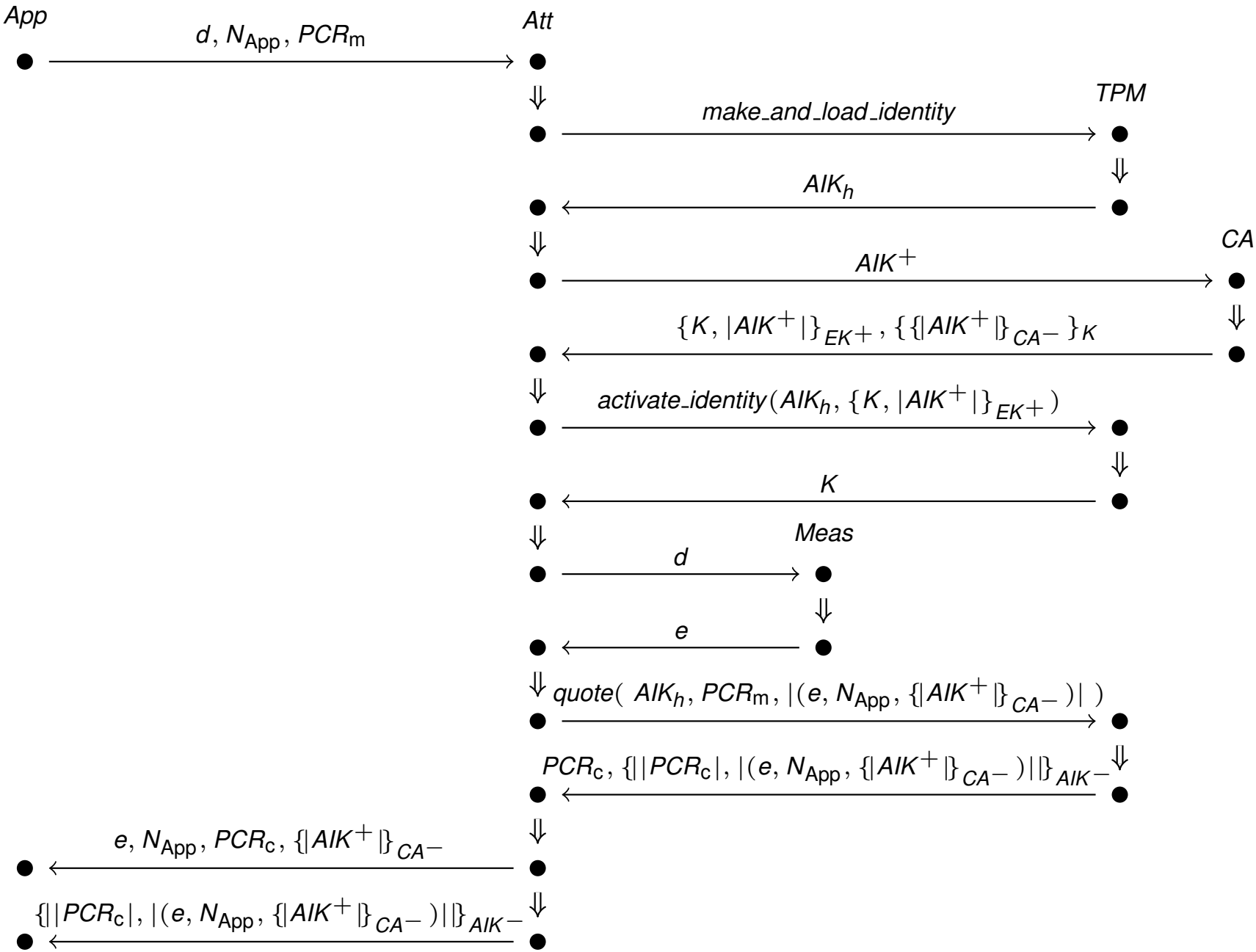
Measurement and Attestation



System-Level Architecture



Privacy CA Attestation



Negotiation

Protocol

```
do { send t $ r;
     q <- receive t;
     e <- case {p:q | policy?(p)} of
            ∅ : None
            p : send t $ choose(p)
          end;
     case e of
       Some v : appraise(v)
       None : None
     end
}
```

Proposals

$$\{\langle E_0, P_0\rangle, \langle E_1, P_1\rangle, \ldots, \langle E_n, P_n\rangle\}$$

Single Realm Attestation

Protocol

```
do { id <- getVCID;
     sig <- getSigFileEvidence;
     src <- getSigFileSrc;
     e <- createEvidence(id,sig,src);
     returnEvidence(e)
}
```

Evidence

$$\langle (id, sig, src), \{||(id, sig, src)|, PCRComp_0||\}_{AIK_0^-} \rangle$$

Protocol

```
do { id <- getVCID;
     sig <- getSigFileEvidence;
     src <- getSigFileSrc;
     srcEvidence <- send src $ r;
     e <- createEvidence(id,sig,src,srcEvidence)
     returnEvidence(e)
}
```

Evidence

$$b = \langle (e), \{||e|, PCRComp_1\|\}_{AIK_1^-} \rangle$$

$$\langle (id, sig, src, b), \{||(id, sig, src, b)|, PCRComp_0\|\}_{AIK_0^-} \rangle$$

Current Status

Completed four demonstrations culminating in running an attestation protocol in response to an attestation request.

- Attestation and Appraisal development
  - CA-Based attestation protocol execution example
  - integration with Berlios TPM 1.2 emulator
  - simple dynamic appraisal of attestation results
- Measurement development
  - on demand Java program measurement
  - HotSpot-based Java VM run time measurements
  - standard mechanism for extending measurement capabilities
- Communication infrastructure
  - vchan, TCP/IP and socket communication infrastructure
  - language-based interface with TPM 1.2
  - JSON-based data exchange formats
  - initial certificate authority API

Goals and Milestones for 2015

Increased functionality and robustness

- Push to the cloud
  - integration with OpenStack
  - migration across Xen instances
  - vTPM function migration
- Establish roots-of-trust and trust argument
  - measured launch and remeasurement of ArmoredSoftware
  - establish trust in the Xen/OpenStack infrastructure
- Executable protocol representation and protocol semantics
  - richer protocol collection
  - evidence of proper execution
  - protocol-centered appraisal
- Operational, integrated vTPM prototype
  - integration with TPM 1.2
  - find and integrate, not build (we hope)

Goals and Milestones for 2015

- More robust communication and system services
  - Armor Authority prototype
  - Certificate Authority integration
  - communications management
- More capable measurement
  - compiler directed measurement
  - continuous measurement of trends
- More interesting download-able demonstration
  - sponsor-defined problem
  - more realistic attacker model

References

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