

ArmoredSoftware: Trust in the cloud

Annual Demonstration

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Introduction and Project Goals

- Big Picture

- Implementation

Prototype demonstration and discussion

- Refine big picture to current demo

- Protocol Execution

- Appraisal

- Attestation Protocol Execution

- Measurement

- Communication

Short term goals and milestones

Questions and guidance



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



- ▶ 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



- ▶ 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



Research & Development Plan

- ▶ **Development and integrate measurement capabilities**
 - ▶ hosted languages (Java)
 - ▶ traditional compiled languages (C, C++)
 - ▶ integrate with environment measurers (Xen, OpenStack, OS)
- ▶ **Develop attestation capabilities**
 - ▶ flexible, user configurable protocol representation
 - ▶ measured protocol execution
 - ▶ protocol execution appraisal
- ▶ **Develop infrastructure trust argument**
 - ▶ develop lightweight vTPM infrastructure supporting mobility
 - ▶ launch from known roots of trust
 - ▶ maintain trust evidence at run time
 - ▶ maintain trust over migration



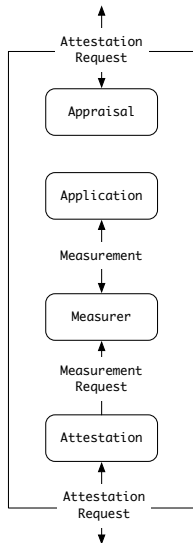
Research & Development Plan

- ▶ Automated synthesis and verification
 - ▶ measurer synthesis at application compile time
 - ▶ automated evidence appraisal from protocols
 - ▶ formal trust argument
- ▶ Demonstrations
 - ▶ initial simple infrastructure demonstrations
 - ▶ cloud-based “big data” environment demonstration
 - ▶ federated trust demonstration
 - ▶ *demonstrations as discovered/directed*
- ▶ Scale up and roll out
 - ▶ integration with Xen, OpenStack, Linux
 - ▶ installation management and packaging
 - ▶ effective web presence

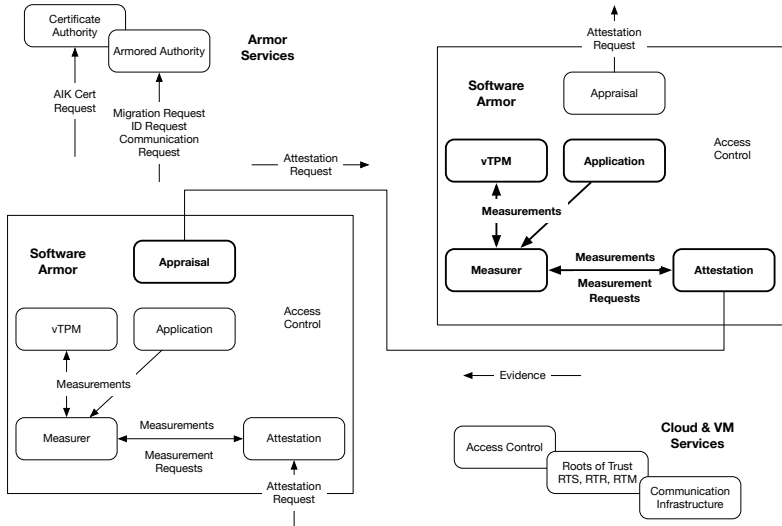


Armored Application Architecture

- ▶ 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*



System-Level Architecture

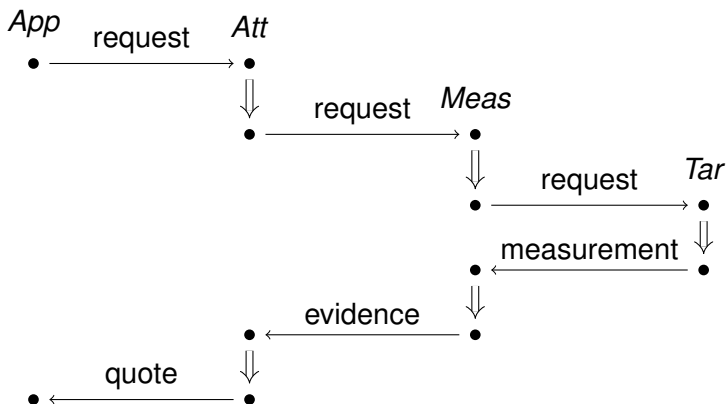


What We Are Demonstrating

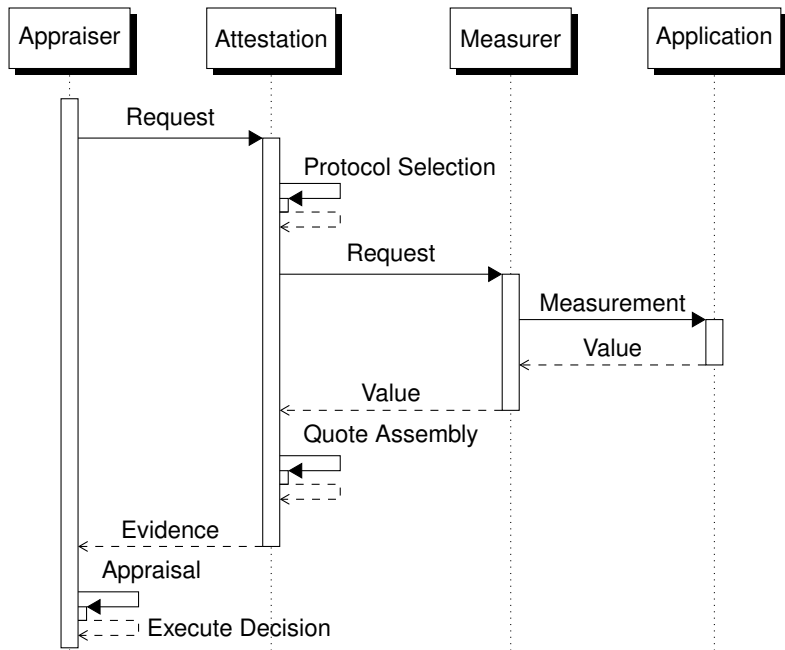
- ▶ Execution of a CA-based Attestation Protocol
 - ▶ Attestation request
 - ▶ Protocol execution
 - ▶ Evidence appraisal
- ▶ Major architectural subsystems
 - ▶ Appraiser
 - ▶ Attestation Manager
 - ▶ Measurer
 - ▶ Instrumented JVM
 - ▶ vTPM and Certificate Authority
- ▶ Anomaly Detection
 - ▶ Bad signatures and PCRs
 - ▶ Bad CA certificates
 - ▶ Bad quotes and AIKs
 - ▶ Bad measurements



Abstract CA-Based Attestation Protocol



Abstract CA-Based Attestation Protocol



Message List Representation

$App \rightarrow Att : d, N_{App}, PCR_m \text{ on } C_{AppAtt}$

$Att \rightarrow TPM : make_and_load_identity \text{ on } C_{AttTPM}$

$TPM \rightarrow Att : AIK^+, AIK_h \text{ on } C_{TPMAtt}$

$Att \rightarrow CA : Att, AIK^+ \text{ on } C_{AttCA}$

$CA \rightarrow Att : \{K, |AIK|\}_{EK^+}, \{[AIK^+]_{CA-}\}_{K^+} \text{ on } C_{CAAtt}$

$Att \rightarrow TPM : activate_identity(AIK_h, |AIK|) \text{ on } C_{AttTPM}$

$TPM \rightarrow Att : K \text{ on } C_{TPMAtt}$

$Att \rightarrow Meas : d \text{ on } C_{AttMeas}$

$Meas \rightarrow Att : e \text{ on } C_{MeasAtt}$

$Att \rightarrow TPM : quote(AIK_h, PCR_m, |(e, N_{App}, [AIK^+]_{CA-})|) \text{ on } C_{AttTPM}$

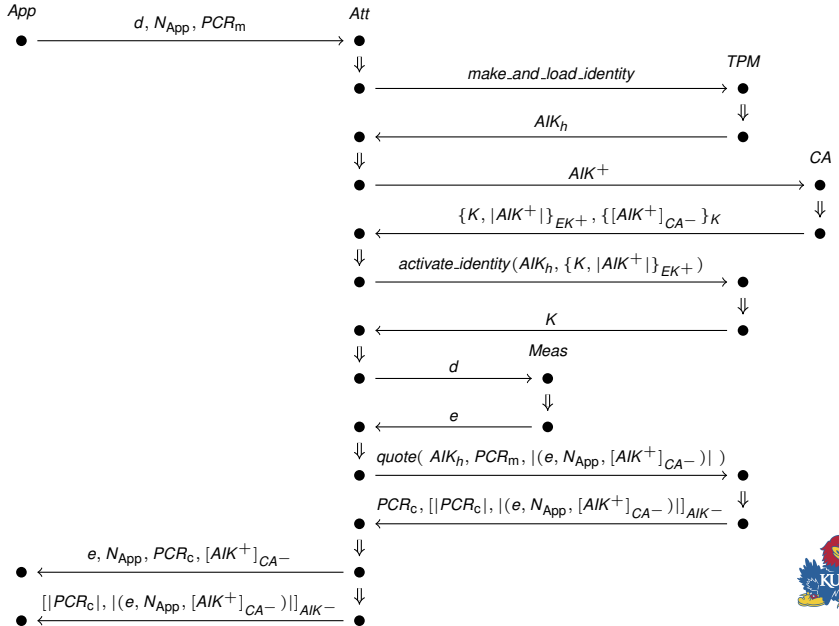
$TPM \rightarrow Att : PCR_c, [|PCR_c|, |(e, N_{App}, [AIK^+]_{CA-})|]_{AIK-} \text{ on } C_{TPMAtt}$

$Att \rightarrow App : e, N_{App}, PCR_c, [AIK^+]_{CA-} \text{ on } C_{AttApp}$

$Att \rightarrow App : [|PCR_c|, |(e, N_{App}, [AIK^+]_{CA-})|]_{AIK-} \text{ on } C_{AttApp}$



Strand Space Diagram Representation



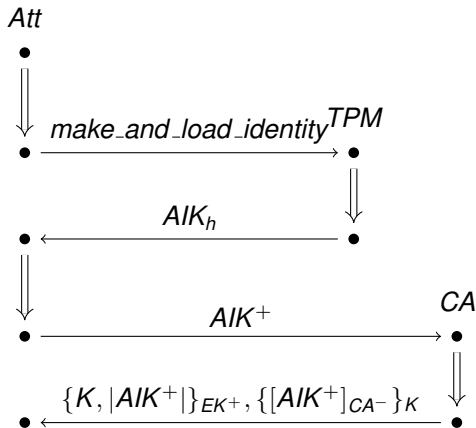


- ▶ Initiate with an attestation request
 - ▶ d abstractly defines desired evidence
 - ▶ N_{App} is the appraiser's nonce
 - ▶ PCR_m selects PCRs
- ▶ Attestation agent selects and executes protocol based on request

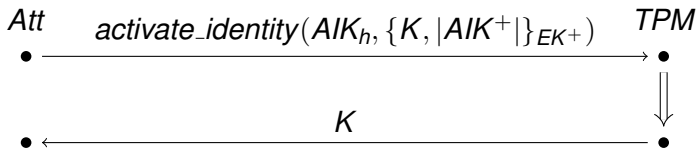


Generating and Certifying an AIK

- ▶ Request a new *AIK* from TPM (optional)
- ▶ Receive *AIK* handle
- ▶ Request AIK^+ signed by CA (*AIK* cert)
- ▶ Receive *AIK* cert encrypted with session key K
- ▶ Receive K encrypted with public EK

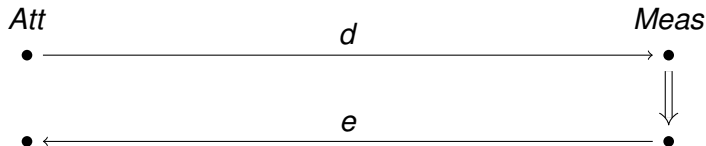


Activating the AIK



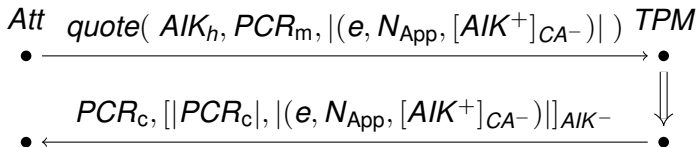
- ▶ Request TPM decryption of the *AIK* cert
- ▶ Receive *K* used to decrypt signed public *AIK*
- ▶ Only TPM can gain access to *K*
- ▶ Only TPM can obtain signed, public *AIK*
- ▶ Oddly, No manipulation of the *AIK* in this “activation” process





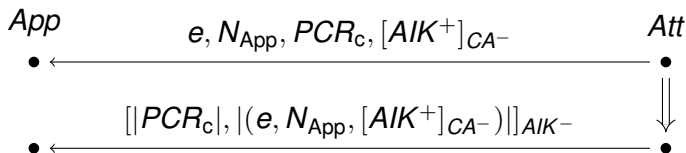
- ▶ Request information from measurer
- ▶ Receive evidence e from measurer
- ▶ d is abstract allowing protocol reuse
- ▶ Most protocols make many requests of the measurer





- ▶ Request a quote from the TPM
 - ▶ AIK identifies the signing AIK
 - ▶ PCR_m identifies desired PCRs
 - ▶ $|(e, N_{App}, [AIK^+]_{CA-})|$ guarantees integrity of returned evidence
- ▶ Receive quote from TPM
 - ▶ PCR_c is PCR composite built from requested PCRs
 - ▶ $[|PCR_c|, |(e, N_{App}, [AIK^+]_{CA-})|]_{AIK-}$ is the signed quote





- ▶ Receive evidence from the attestation manager
 - ▶ evidence
 - ▶ original nonce
 - ▶ PCR composite
 - ▶ signed AIK^+
- ▶ Receive TPM quote from the attestation manager
 - ▶ hash of all evidence
 - ▶ PCR composite
 - ▶ signed by AIK^-
- ▶ Evaluate evidence and quote



Demonstration detects failure of all aspects of attestation

$$e, N_{\text{App}}, PCR_C, [AIK^+]_{CA^-}$$

- ▶ e – evidence gathered from running application
- ▶ N_{App} – prevents replay
- ▶ PCR_C – evidence in the form of PCR data from the vTPM
- ▶ $[AIK^+]_{CA^-}$ – ensures validity of AIK^+

$$[|PCR_C|, |(e, N_{\text{App}}, [AIK^+]_{CA^-})|]_{AIK^-}$$

- ▶ PCR_C – hash ensures integrity of PCR data
- ▶ $|(e, N_{\text{App}}, [AIK^+]_{CA^-})|$ – hash ensures integrity of evidence, nonce, and signed AIK^+



Attestation Protocol Execution



3-4 Slides on Measurement



2-3 Slides on Communication Mechanisms



Shared notion of AIKCertRequest, AIKCert, and CAResponse JSON structures.

Attester

- ▶ creates an AIKCertRequest (containing attester ID , AIK^+) and converts to JSON
- ▶ JSON sent as POST request to CA running as web server

Certificate Authority

- ▶ POST body bytes \rightarrow UTF8 \rightarrow JSON \rightarrow AIKCertRequest
- ▶ looks up EK^+ associated with ID in sql database
- ▶ $AIKCert = AIK^+$ signed with CA^-
- ▶ generates key K and encrypts with EK^+
- ▶ AIKCert encrypted with K
- ▶ both wrapped in a CAResponse, converted to JSON and sent as response.



Properties

- ▶ CA only responds to receiving an *AIKCertRequest*_{JSON}
- ▶ The CACert can *only* be decrypted by knowing K (and therefore EK^-)

Appraiser Knowledge after receiving Cert:

- ▶ signature on *AIK* ensures it was CA who generated signature
+
- ▶ only an entity knowing EK^- could decrypt and send the CACert
=
- ▶ **Attester is using a registered TPM**



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




- ▶ Push to the cloud
- ▶ Establish roots of trust and trust argument
- ▶ Executable protocol representation and protocol semantics
- ▶ Operational, integrated vTPM prototype
- ▶ Name Server / Certificate Authority prototype
- ▶ More capable measurement
- ▶ Downloadable demonstration



Questions and Guidance

- ▶ What problems are interesting?
- ▶ What problem would be a nice attention grabber?
- ▶ What should we be watching and integrating with?



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