

# 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

- Attestation Protocol Execution

- Appraisal

- 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



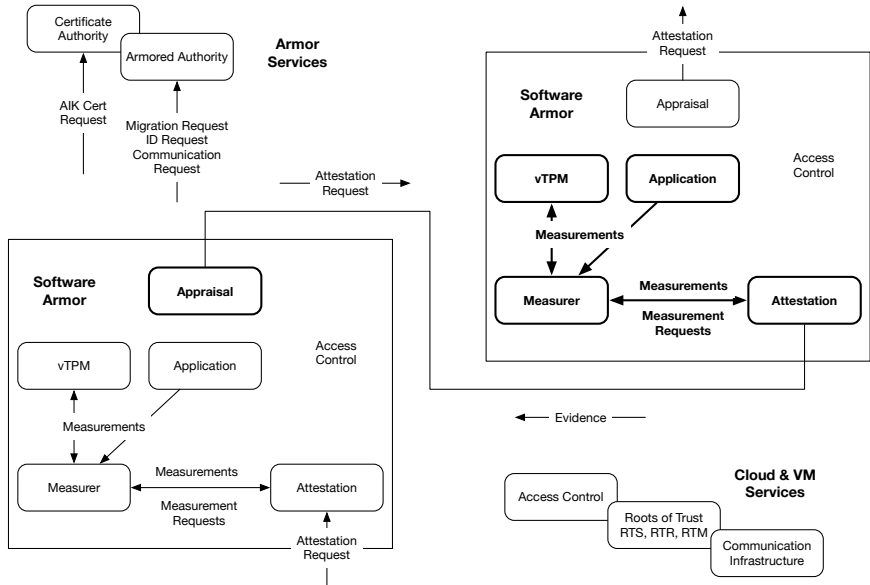
- ▶ Lightweight integration with existing cloud infrastructure
  - ▶ OpenStack cloud infrastructure
  - ▶ Xen+XSM VM infrastructure
  - ▶ Fedora, HotSpot JVM, GHC
- ▶ Trusted Computing Group standards compliant
  - ▶ Trusted Platform Module 1.2
  - ▶ TCG vTPM (in principle)
  - ▶ Trusted OS infrastructure
- ▶ 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



# High-Level Architecture

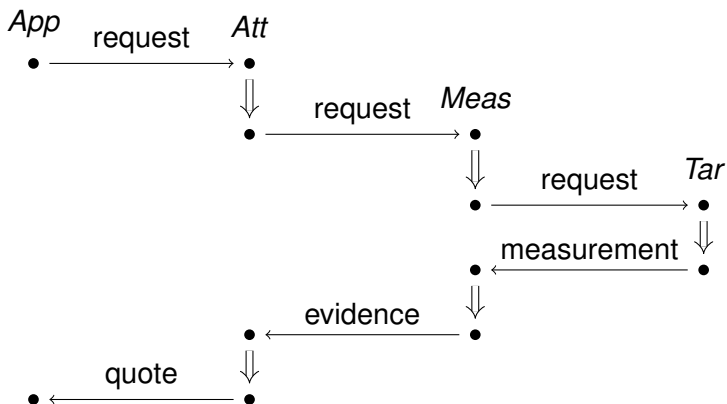


# What We Are Demonstrating

- ▶ 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

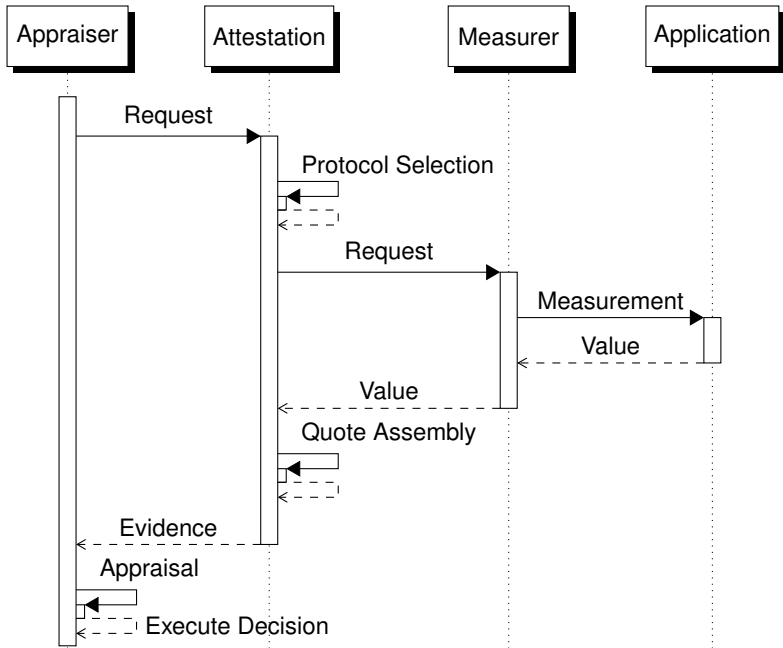


# Abstract CA-Based Attestation Protocol





# Abstract CA-Based Attestation Protocol



# Message List Representation

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

$Att \rightarrow TPM : make\_and\_load\_identity \text{ on } C_{AttTPM}$

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

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

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

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

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

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

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

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

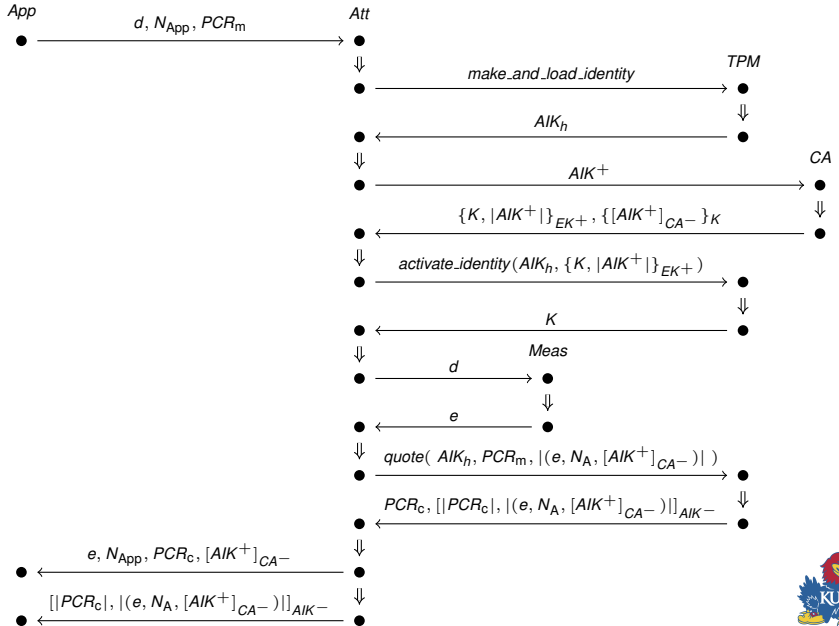
$TPM \rightarrow Att : PCR_c, [|PCR_c|, |(e, N_A, [AIK^+]_{CA^-})|]_{AIK^-} \text{ on } C_{TPMAtt}$

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

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



# Strand Space Diagram Representation



# Attestation Request

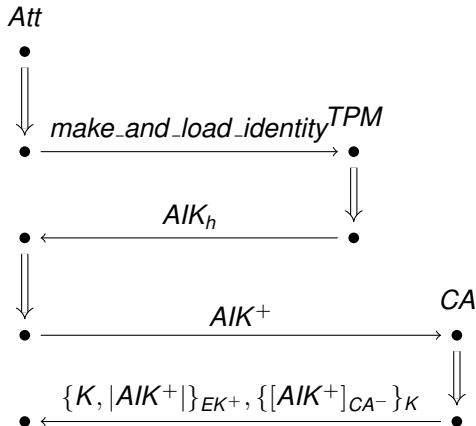


- ▶ Initiate with an attestation request
  - ▶  $d$  abstractly defines desired evidence
  - ▶  $N_{\text{App}}$  is the appraiser's nonce
  - ▶  $\text{PCR}_m$  selects PCRs
- ▶ Attestation agent selects and executes protocol based on request

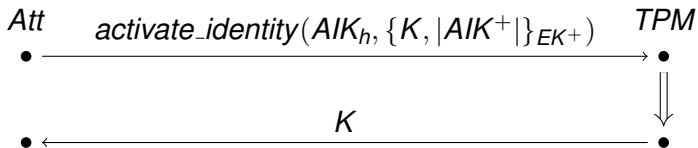


# Generating and Certifying an AIK

- ▶ 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  $EK$

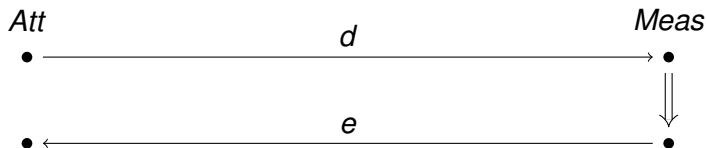


## Activating the AIK



- ▶ 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

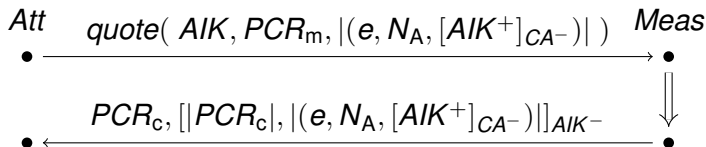




- ▶ Request information from measurer
- ▶ Receive evidence  $e$  from measurer
- ▶  $d$  is abstract allowing protocol reuse
- ▶ Most protocols make many requests of the measurer



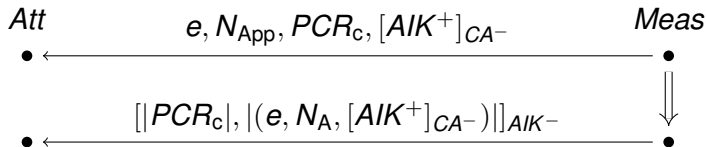
# Generating a Quote



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







- Receive quote from the attestation manager
- Receive evidence from the attestation manager
- Evaluate evidence and quote



## 3-4 Slides on Attestation Protocol Execution



# 1-2 Slides on Appraisal



## 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 TPM\_PUBKEY associated with ID in sql database
- ▶ AIKCert  $\approx$  AIK signed with  $CA_1$
- ▶ generates key  $K$  and encrypts with TPM\_PUBKEY
- ▶ AIKCert encrypted with  $K$
- ▶ both wrapped in a CAResponse, converted to JSON and sent as response.



## Properties

- ▶ CA only responds to receiving an *AIKCertRequest<sub>JSON</sub>*
- ▶ The CACert can *only* be decrypted by knowing *K* (and therefore TPM\_PRIVATEKEY)

## Appraiser Knowledge after receiving Cert:

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



# 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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