ArmoredSoftware: Trust in the cloud

Annual Demonstration

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Outline

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

Program Goal

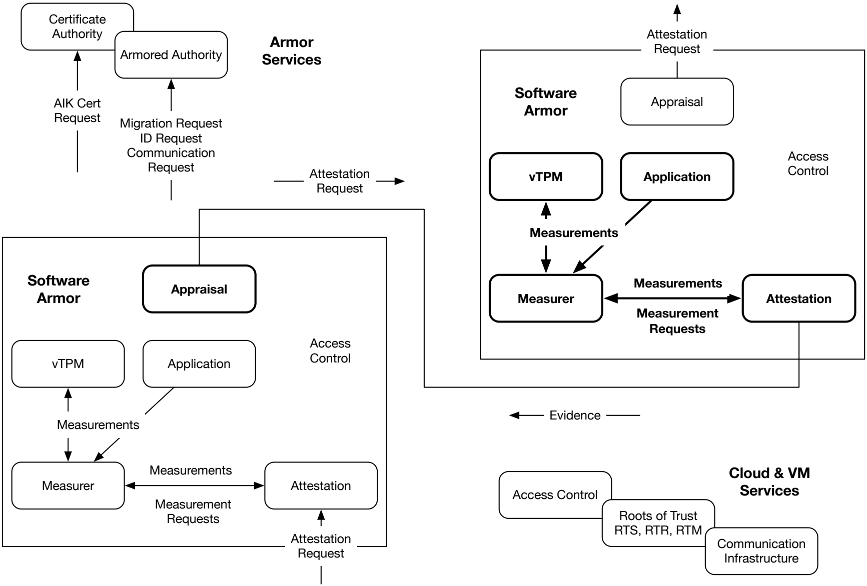
Trust in the Cloud

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

New Capabilities

- 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
  - targeting TXT, Xen, Linux, and OpenStack infrastructure
  - user-space measurement and attestation

High-Level Architecture



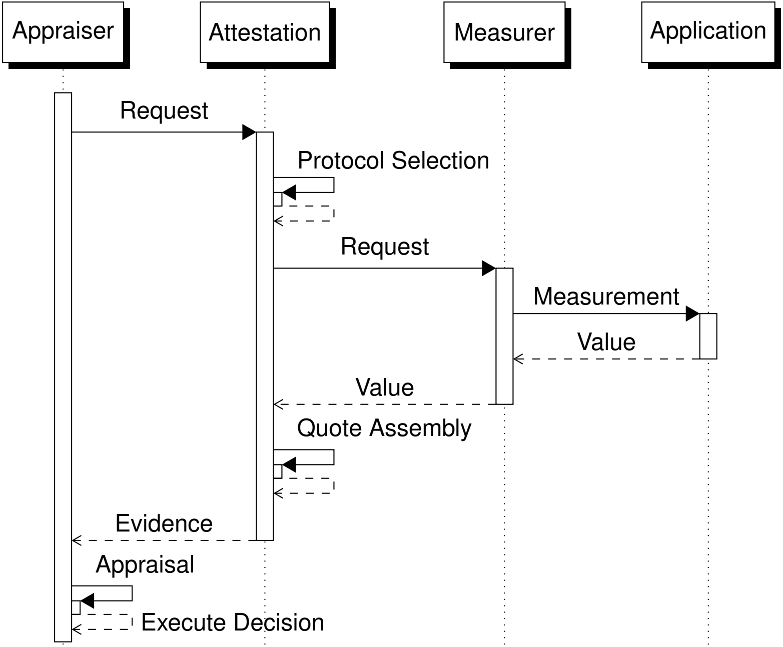
Implementation Decisions

- Standard delivery platform
  - Xen+XSM VM infrastructure
  - OpenStack cloud infrastructure
  - Fedora, HotSpot JVM, GHC
- Standard communication mechanisms
  - JSON structures for all exchanged data
  - *vchan* for on-platform communication
  - TCP/IP for off-platform communication
- Trusted Computing Group standards compliant
  - Trusted Platform Module (TPM) 1.2
  - TCG vTPM in principle
- Executable protocol representation
  - protocol fragments as first-class structures
  - strand space formal semantics

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



Message List Representation

$App \to Att : d, N_{\mathrm{App}}, PCR_{\mathrm{m}}$ on C_{AppAtt}

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

$TPM \to Att : AIK^{+}, AIK_{h}$ on C_{TPMAtt}

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

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

$Att \to TPM : activate\_identity(AIK_{h}, |AIK|)$ on C_{AttTPM}

$TPM \to Att : K$ on C_{TPMAtt}

$Att \to Meas : d$ on $C_{AttMeas}$

$Meas \to Att : e$ on $C_{MeasAtt}$

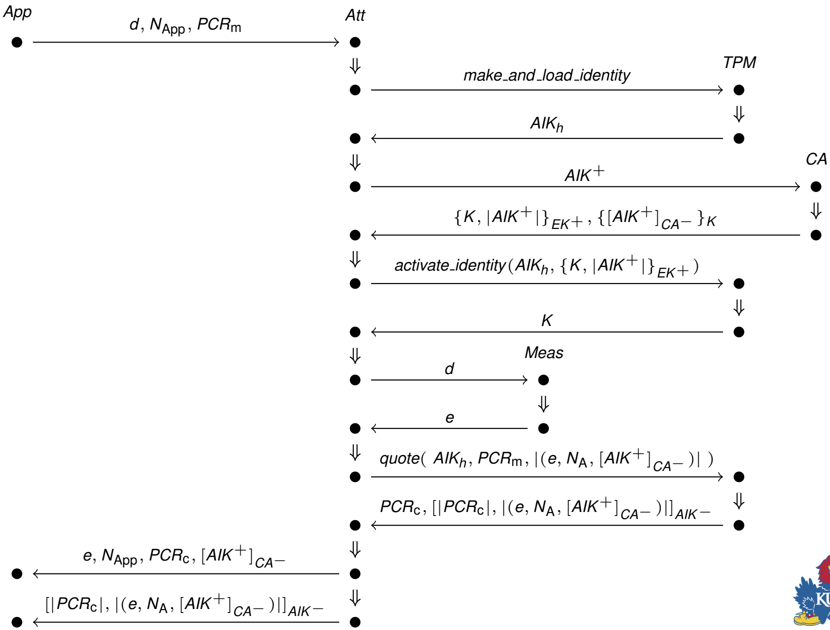
$Att \to TPM : quote(\ AIK_{\mathrm{h}}, PCR_{\mathrm{m}}, |(e, N_{\mathrm{A}}, [AIK^{+}]_{CA^{-}})|\ )$ on C_{AttTPM}

$TPM \to Att : PCR_{\mathrm{c}}, [|PCR_{\mathrm{c}}|, |(e, N_{\mathrm{A}}, [AIK^{+}]_{CA^{-}})|]_{AIK^{-}}$ on C_{TPMAtt}

$Att \to App : e, N_{\mathrm{App}}, PCR_{\mathrm{c}}, [AIK^{+}]_{CA^{-}}$ on C_{AttApp}

$Att \to App : [|PCR_{\mathrm{c}}|, |(e, N_{\mathrm{A}}, [AIK^{+}]_{CA^{-}})|]_{AIK^{-}}$ on C_{AttApp}

Strand Space Diagram Representation



App

Att

TPM

CA

Meas

$d, N_{\mathrm{App}}, PCR_{\mathrm{m}}$

make_and_load_identity

AIK_h

AIK^+

$\{K, |AIK^+|\}_{EK+}, \{[AIK^+]_{CA-}\}_K$

$activate\_identity(AIK_h, \{K, |AIK^+|\}_{EK+})$

K

d

e

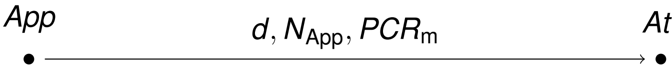
$quote(\ AIK_h, PCR_{\mathrm{m}}, |(e, N_{\mathrm{A}}, [AIK^+]_{CA-})|\ )$

$PCR_{\mathrm{c}}, [|PCR_{\mathrm{c}}|, |(e, N_{\mathrm{A}}, [AIK^+]_{CA-})|]_{AIK-}$

$e, N_{\mathrm{App}}, PCR_{\mathrm{c}}, [AIK^+]_{CA-}$

$[|PCR_{\mathrm{c}}|, |(e, N_{\mathrm{A}}, [AIK^+]_{CA-})|]_{AIK-}$

Attestation Request



App

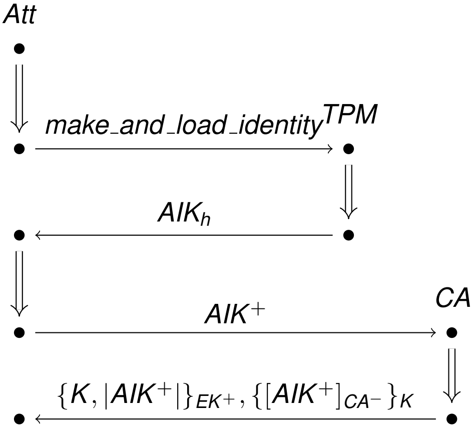
$d, N_{\mathrm{App}}, PCR_{\mathrm{m}}$

Att

- 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*



Att

TPM

CA

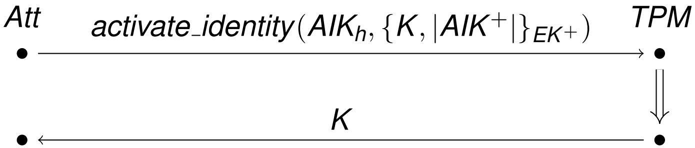
make_and_load_identity

AIK_h

AIK^+

$\{K, |AIK^+|\}_{EK^+}, \{[AIK^+]_{CA^-}\}_K$

Activating the AIK



Att

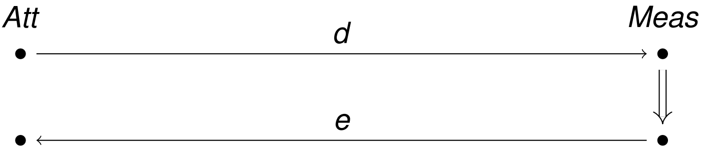
$activate\_identity(AIK_h, \{K, |AIK^+|\}_{EK^+})$

TPM

K

- 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

Measurement



- 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

$$\begin{tikzcd}
\overset{Att}{\bullet} \arrow[rr, "quote(\ AIK\,, PCR_{\mathrm{m}}, |(e, N_{\mathrm{A}}, [AIK^{+}]_{CA^{-}})|\ )"] & & \overset{Meas}{\bullet} \arrow[d, Rightarrow] \\
\bullet & & \bullet \arrow[ll, "PCR_{\mathrm{c}}, [|PCR_{\mathrm{c}}|, |(e, N_{\mathrm{A}}, [AIK^{+}]_{CA^{-}})|]_{AIK^{-}}"']
\end{tikzcd}$$

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

Appraisal

$$\begin{tikzcd}[column sep=huge]
\overset{\mathit{Att}}{\bullet} & \overset{\mathit{Meas}}{\bullet} \arrow[l, "{e, N_{\text{App}}, PCR_{\text{c}}, [AIK^{+}]_{CA^{-}}}"'] \arrow[d, Rightarrow] \\
\bullet & \bullet \arrow[l, "{[|PCR_{\text{c}}|, |(e, N_{\text{A}}, [AIK^{+}]_{CA^{-}})|]_{AIK^{-}}}"']
\end{tikzcd}$$

- 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

CA communication

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 → UTF8 → JSON → AIKCertRequest
- looks up TPM_PUBKEY associated with ID in sql database
- AIKCert ≈ 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.

CA communication continued

Properties

- CA only responds to receiving an $AIKCertRequest_{JSON}$
- 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?

References