ArmoredSoftware: Trust in the cloud

Annual Demonstration

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Outline

Introduction and Project Goals

Prototype demonstration and discussion

Year 2 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

New Technologies

Cloud-based trust infrastructure

- 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

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

Research & Development Plan

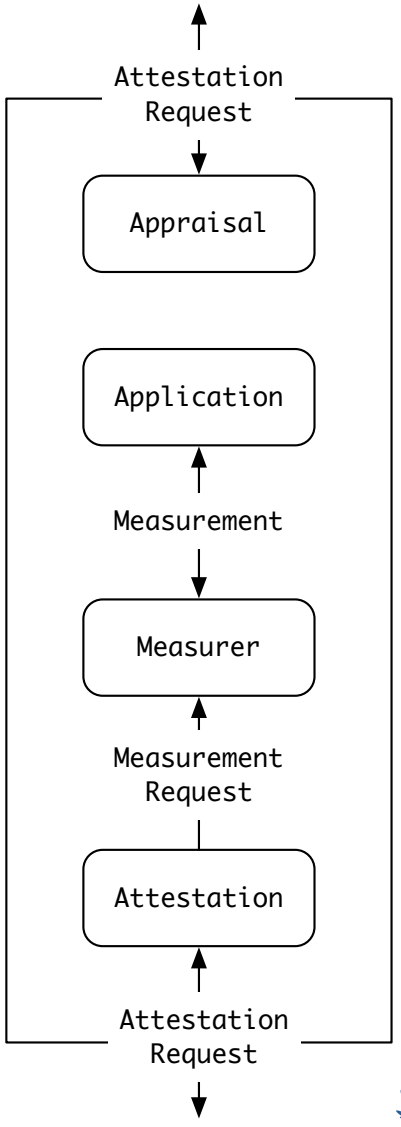
- Development and integrate measurement capabilities
  - hosted languages (Java)
  - traditional compiled languages (C, C++)
  - integrate with environment measurers (Xen,OpenStack,OS)
- Develop attestation capabilities
  - flexible, user configurable protocol representation
  - measured protocol execution
  - 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

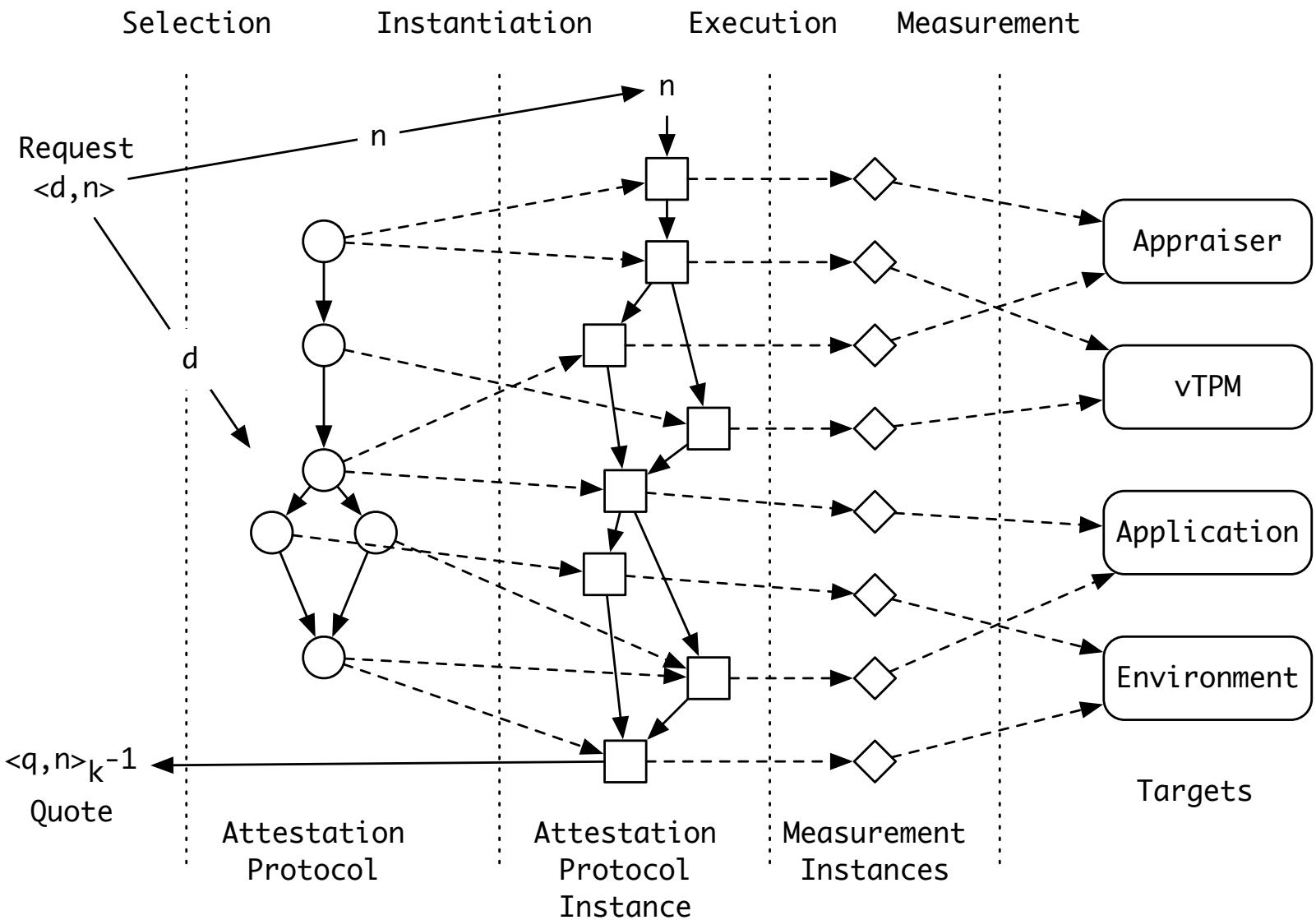
- Automated synthesis and verification
  - measurer synthesis at application compile time
  - automated evidence appraisal from protocols
  - formal trust argument
- Demonstrations
  - initial simple infrastructure demonstrations
  - cloud-based “big data” environment demonstration
  - federated trust 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

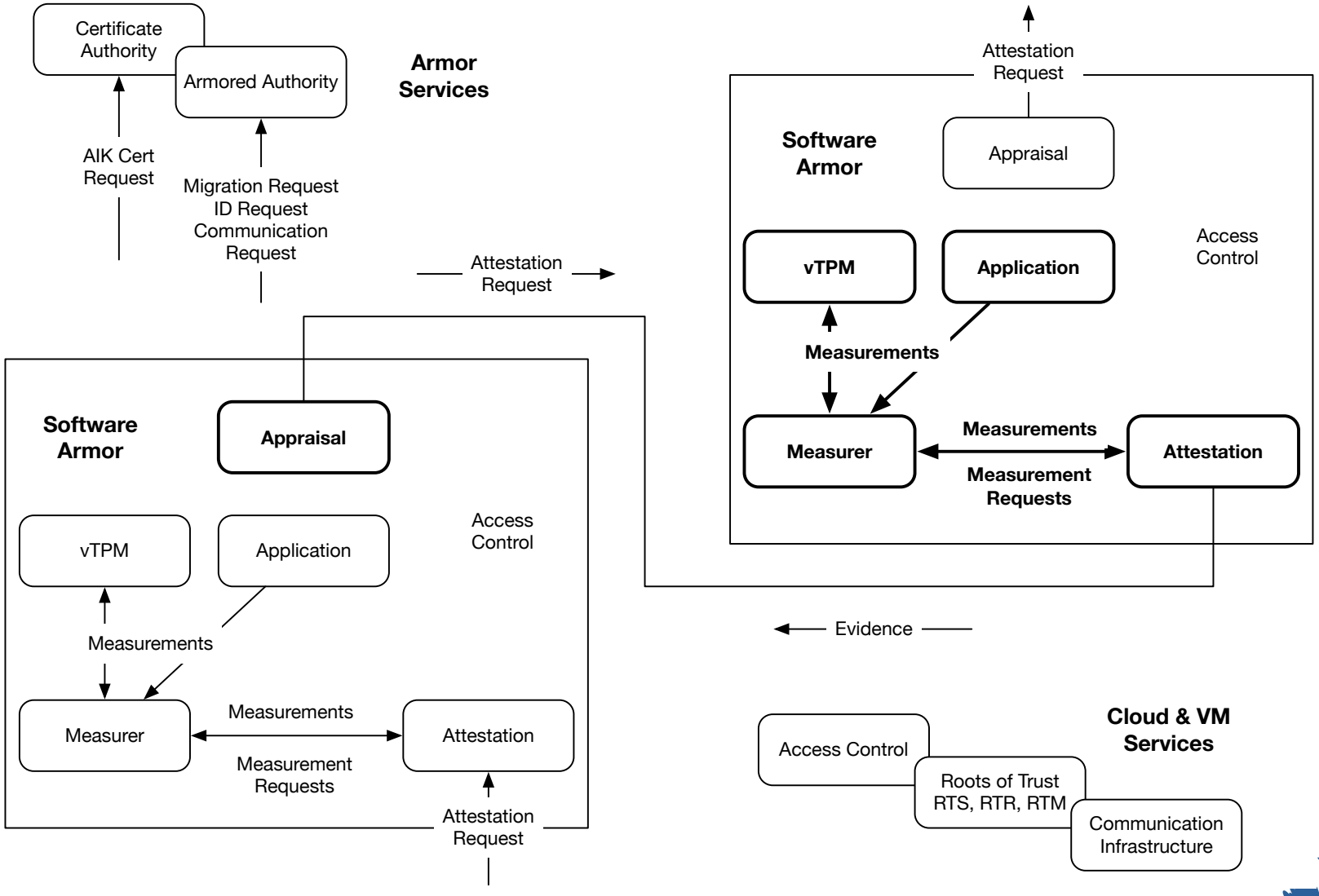
- Focus is user-space applications
- Assesses the cloud infrastructure and environment
- Attests to the state of its application
- High-assurance, lightweight infrastructure
- Support for new and legacy software
- Influenced by the *Trusted Research Platform* and *Principles of Remote Attestation*



Measurement and Attestation



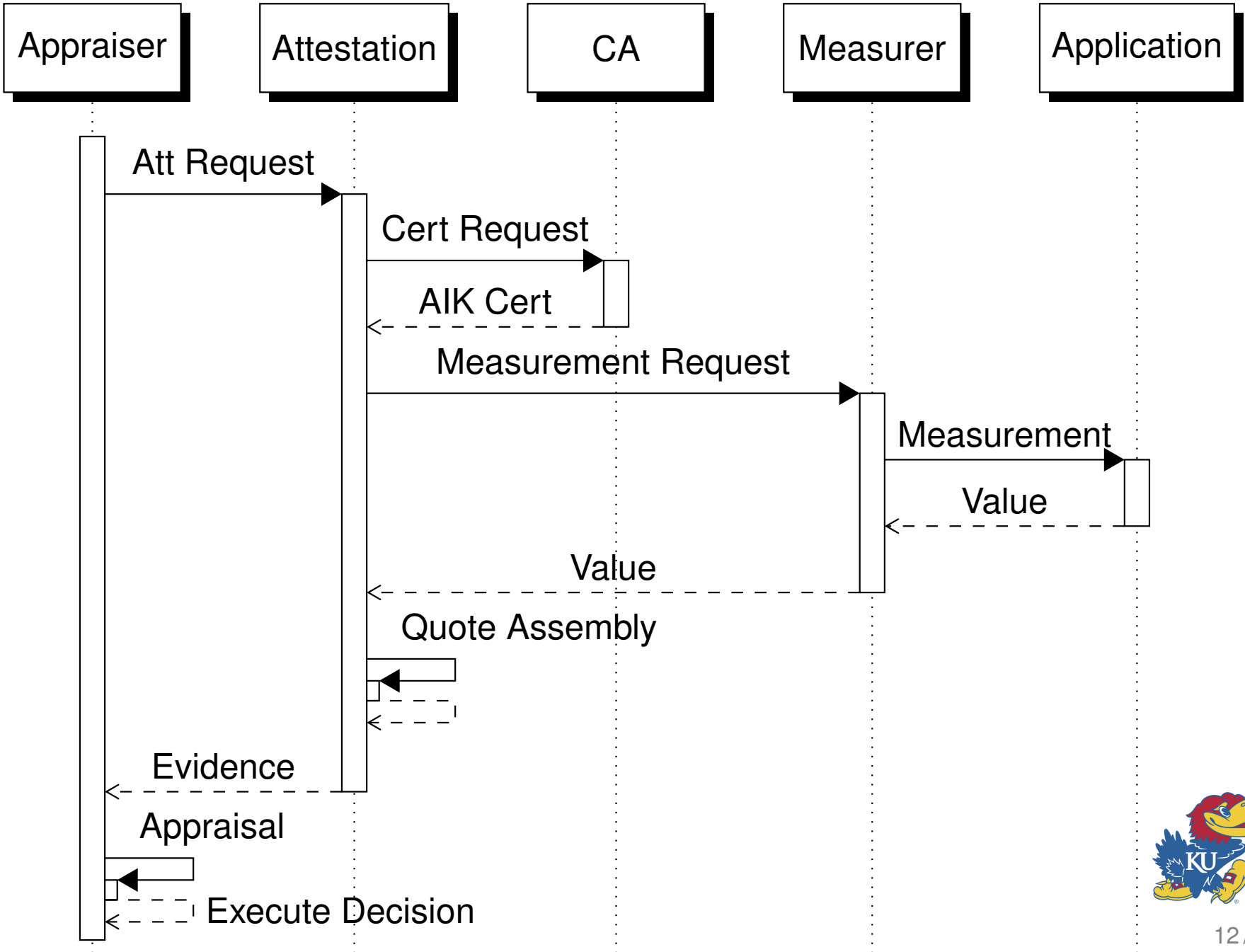
System-Level Architecture



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



Message List Representation

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

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

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

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

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

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

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

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

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

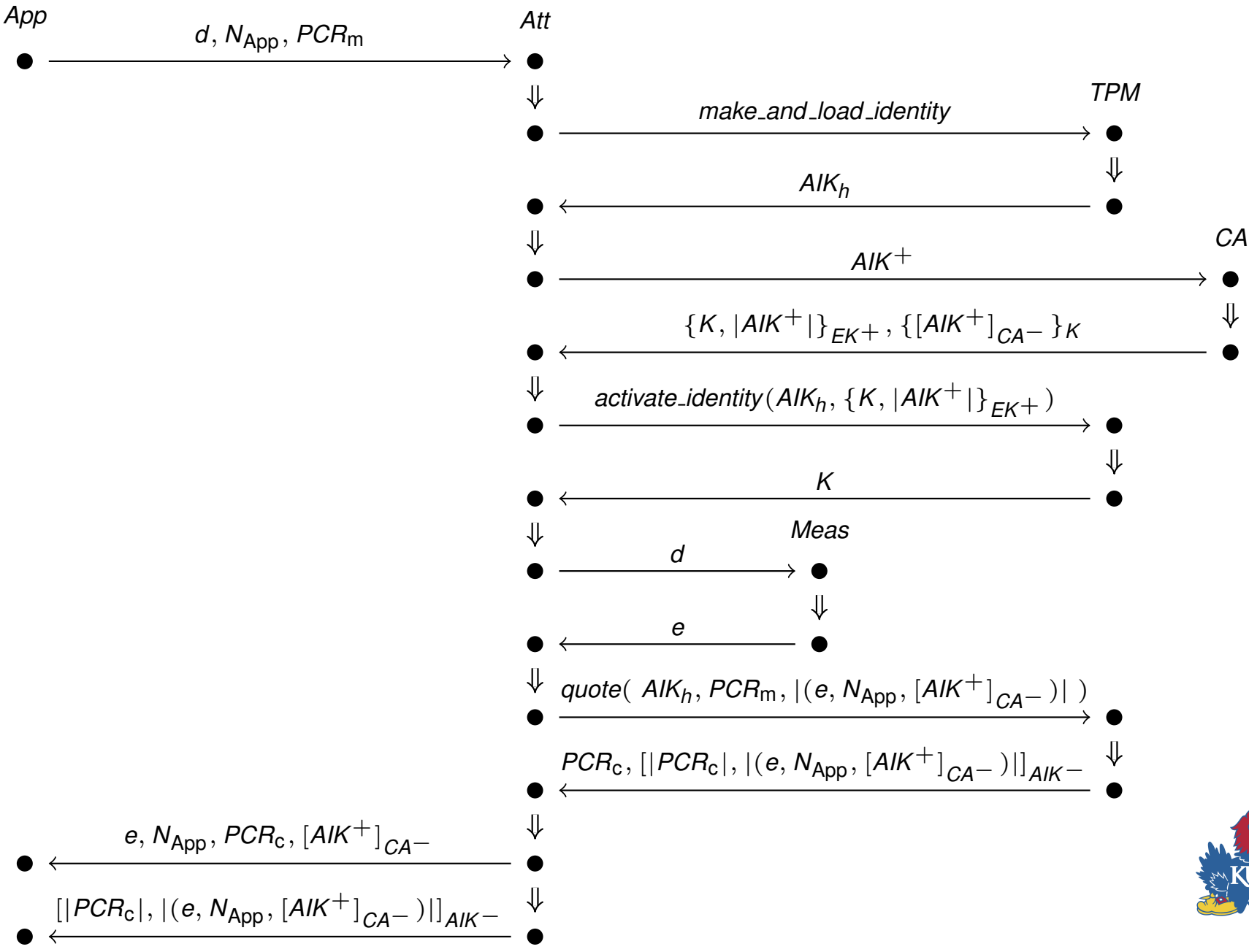
$Att \rightarrow TPM : quote(\ AIK_{\text{h}}, PCR_{\text{m}}, |(e, N_{\text{App}}, [AIK^{+}]_{CA^{-}})|\ )$ on C_{AttTPM}

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

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

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

Strand Space Diagram Representation

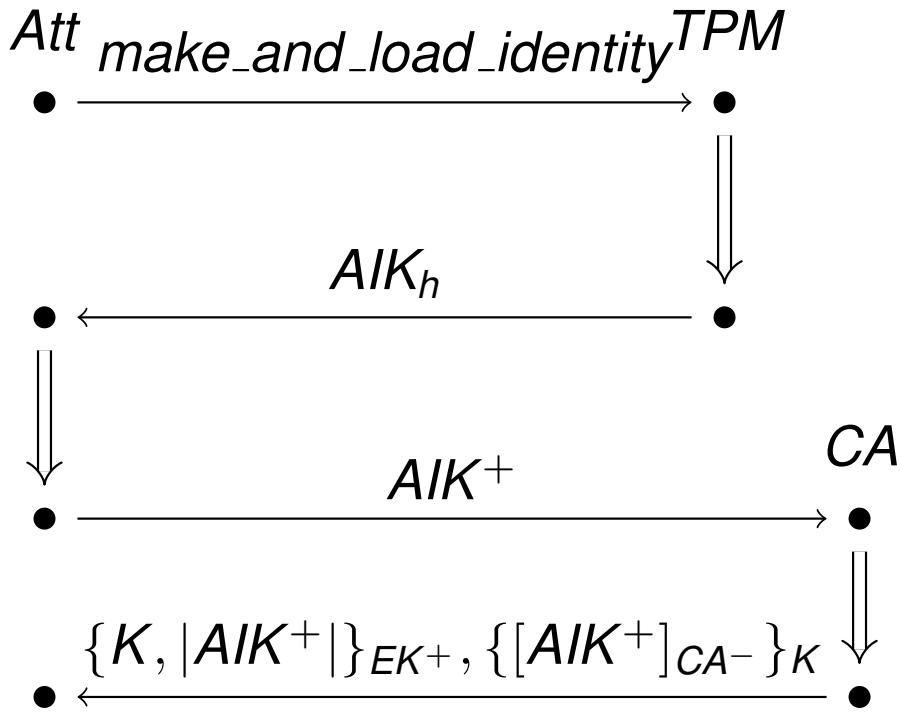


Requesting an Attestation

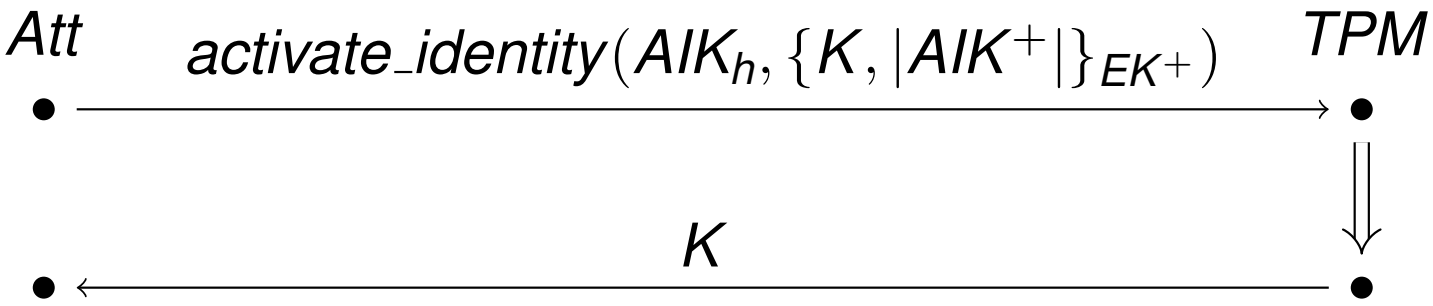
- Initiate with an attestation request
  - d abstractly defines desired evidence
  - N_{App} is the appraiser's nonce
  - PCR_{m} selects PCRs
- Attestation agent selects and executes protocol based on request

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*

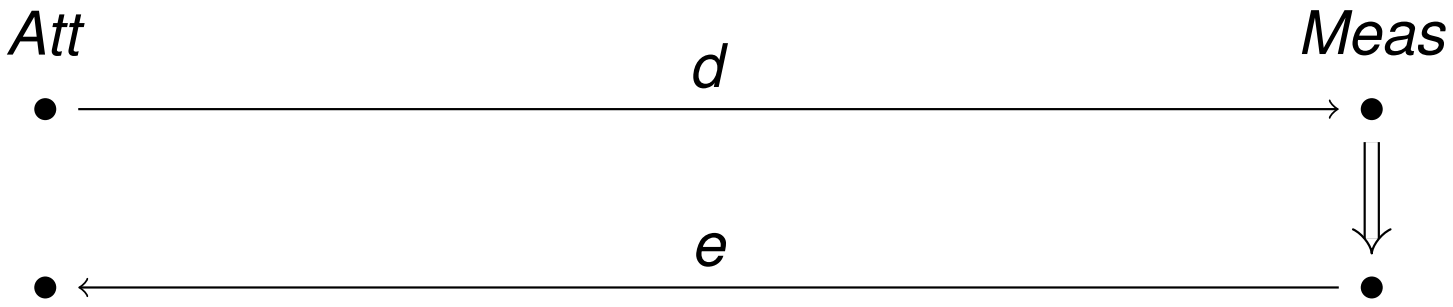


Activating the AIK



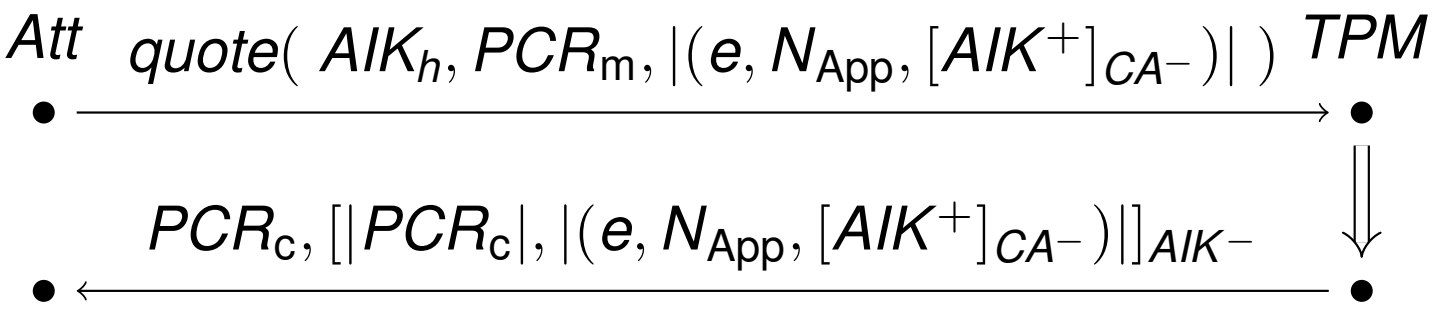
- Request TPM decryption of the *AIK* cert
- Receive K used to decrypt signed public *AIK*
- Only TPM can gain access to K
- Only TPM can obtain signed, public *AIK*
- Oddly, No manipulation of the *AIK* in this “activation” process

Gathering Measurements



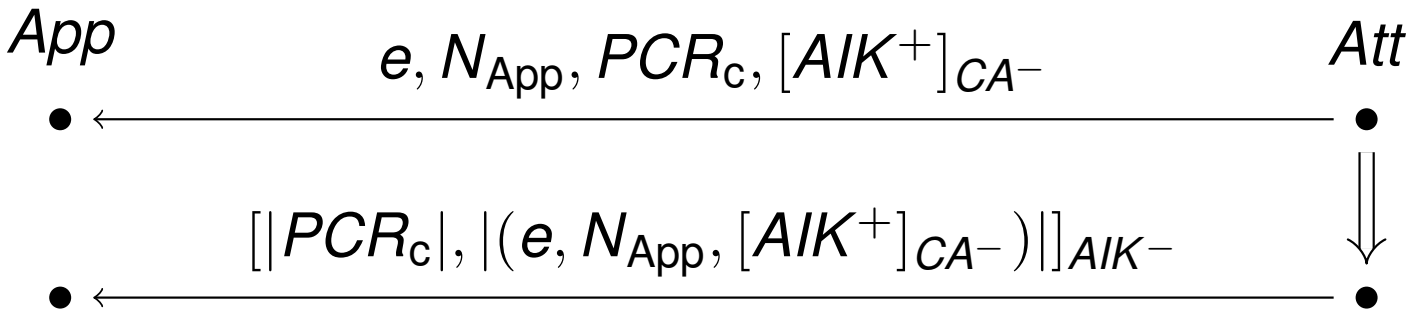
- Request information from measurer
- Receive evidence *e* from measurer
- *d* is abstract allowing protocol reuse
- Most protocols make many requests of the measurer

Generating a Quote



- Request a quote from the TPM
  - AIK identifies the signing AIK
  - PCR_m identifies desired PCRs
  - $|(e, N_{App}, [AIK^+]_{CA^-})|$ 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

Returning Evidence



- 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

Evidence Appraisal

Demonstration detects failure of all aspects of attestation

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

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

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

- 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

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 $\rightarrow$ 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.

CA communication continued

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**

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

- 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

Questions and Guidance

- What should we be watching and integrating with?
  - operational vTPM infrastructure
  - infrastructure measured boot
- What demonstration problems are relevant?
  - federated trust
  - trust in the infrastructure
  - trust among application collections
- What would convince you to work a problem with us?

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